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GEOLOGY AND GROUNDWATER STUDIES IN PART OF THE EDWARDS PLATEAU OF TEXAS, INCLUDING SUTTON AND ADJACENT COUNTIES

April 1966 ARS 41-103
Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

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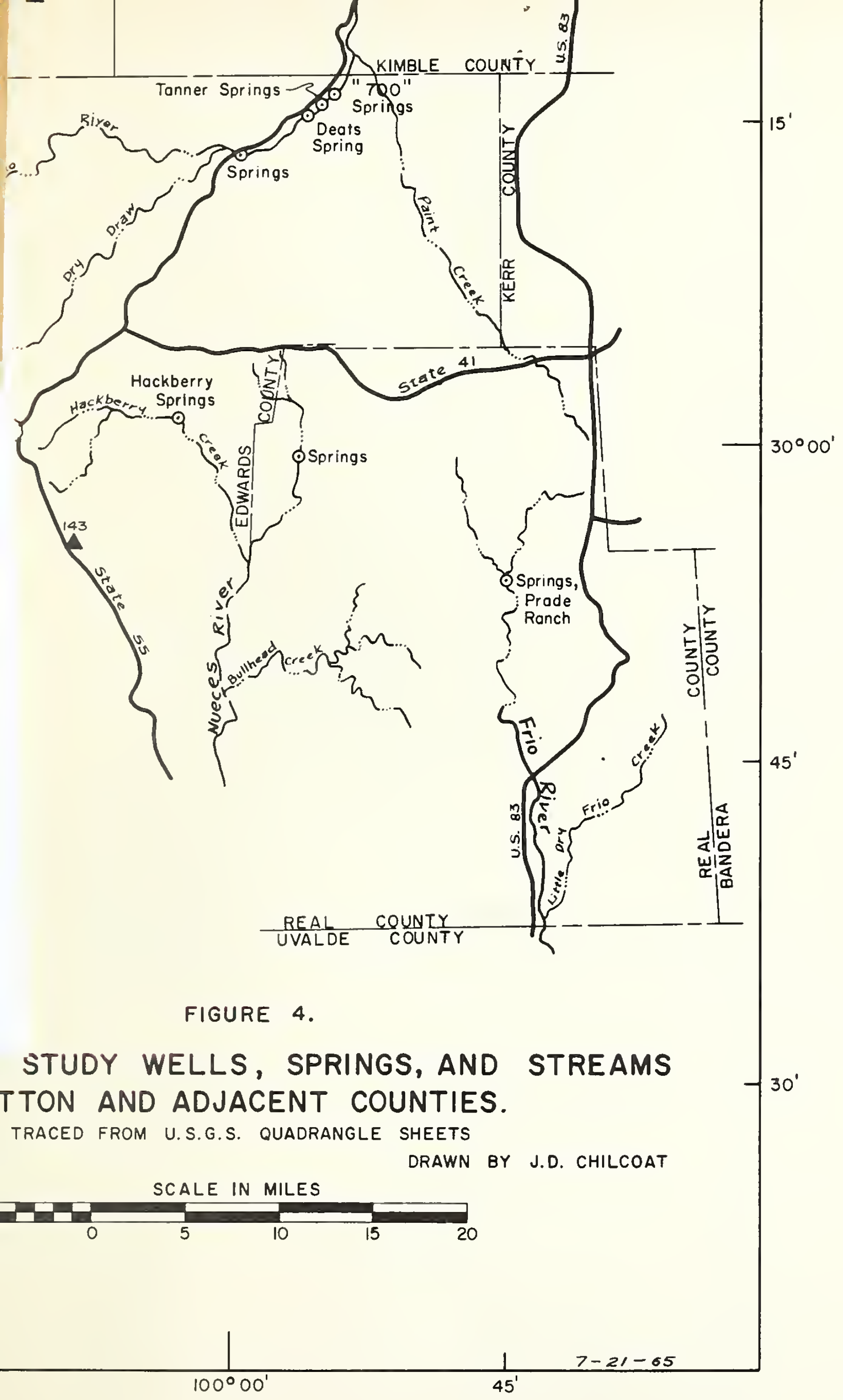

FIGURE 4.

STUDY WELLS, SPRINGS, AND STREAMS
TTON AND ADJACENT COUNTIES.

TRACED FROM U.S.G.S. QUADRANGLE SHEETS

DRAWN BY J.D. CHILCOAT

," ARS 41-103

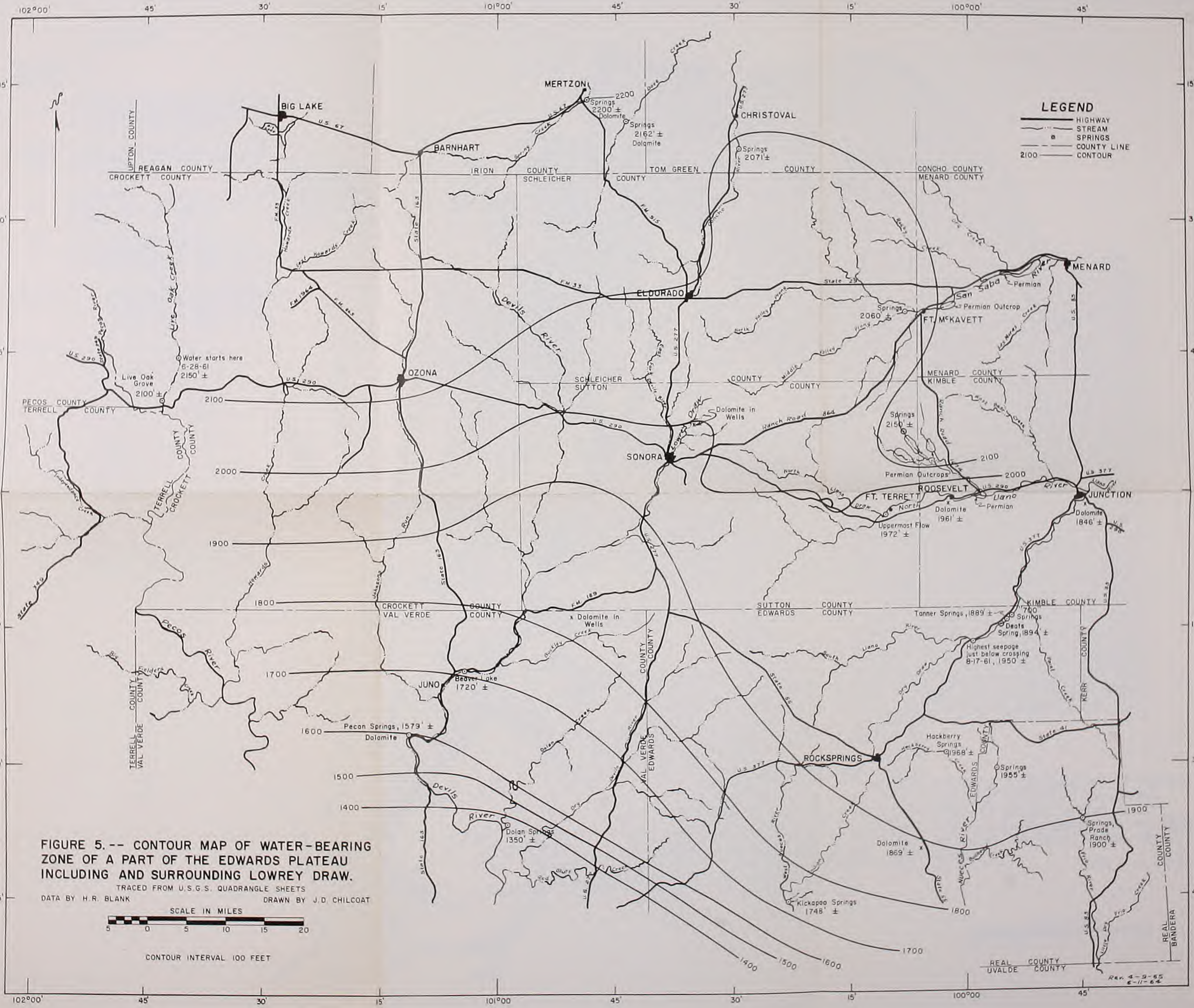

FIGURE 5.-- CONTOUR MAP OF WATER-BEARING ZONE OF A PART OF THE EDWARDS PLATEAU INCLUDING AND SURROUNDING LOWREY DRAW.

TRACED FROM U.S.G.S. QUADRANGLE SHEETS

DATA BY H.R. BLANK

DRAWN BY J.D. CHILCOAT

SCALE IN MILES

5 0 5 10 15 20

CONTOUR INTERVAL 100 FEET

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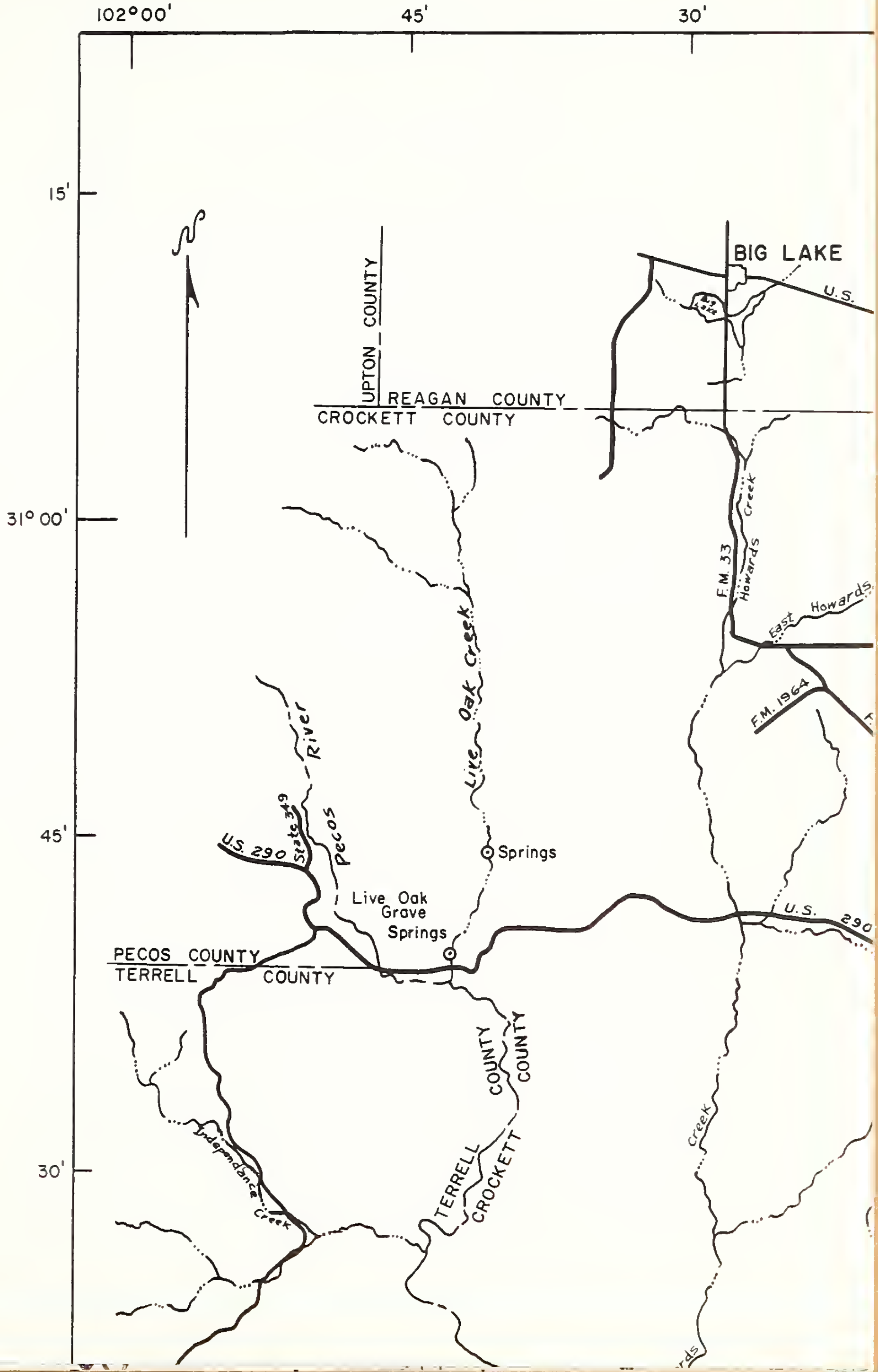

U.S. Department of Agriculture cooperating with the Texas Agricultural Experiment Station and the Te

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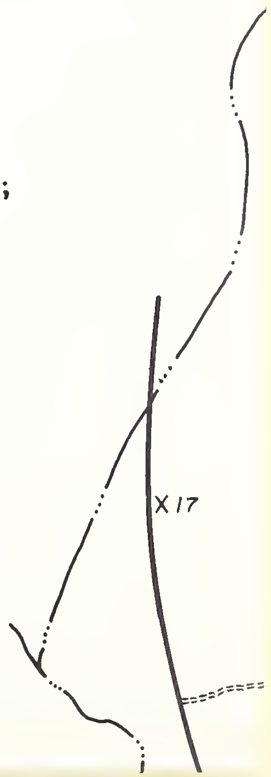
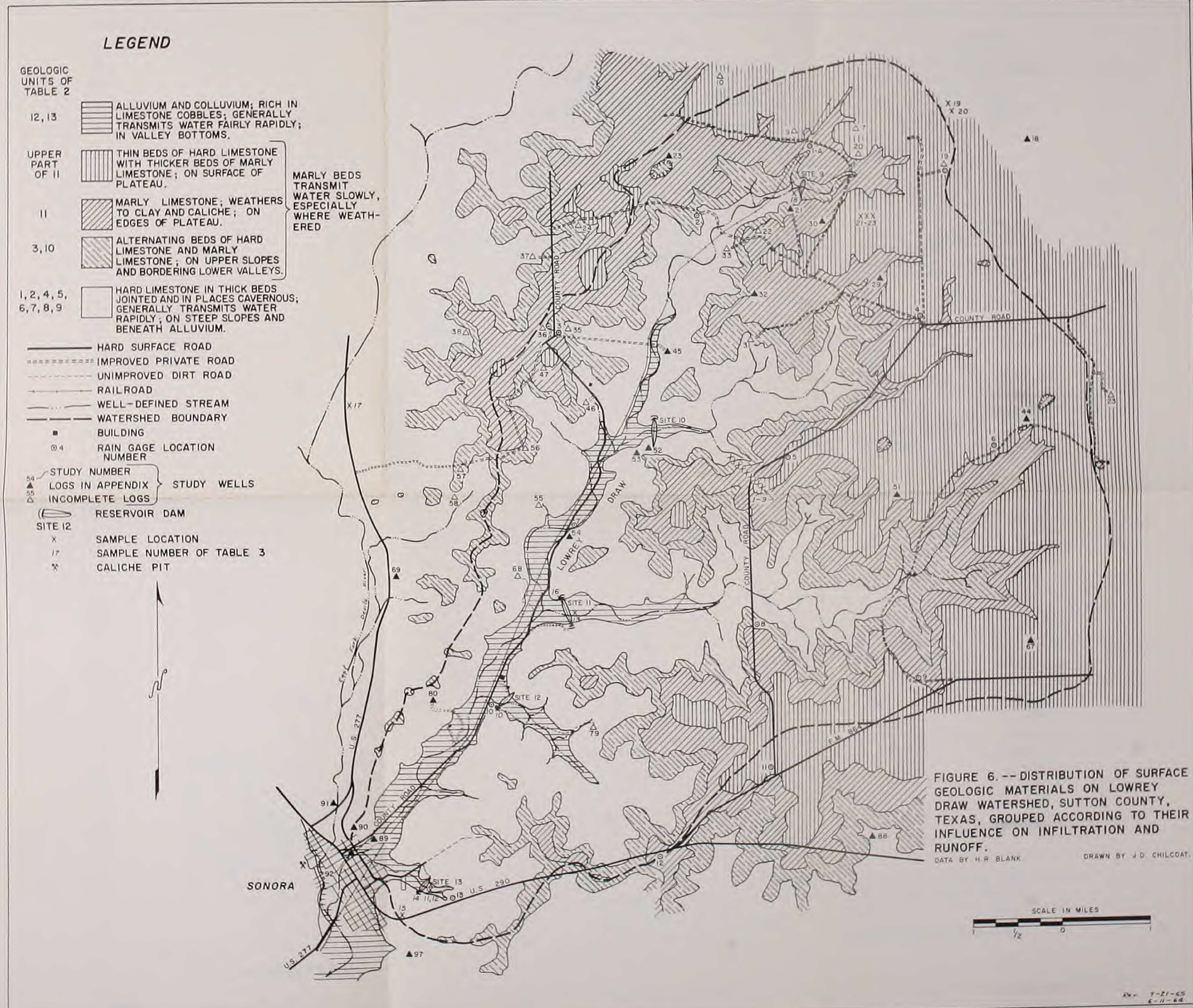
GEOLOGIC UNITS OF TABLE 2			
12, 13	▤	ALLUVIUM AND COLLUVIUM; RICH IN LIMESTONE COBBLES; GENERALLY TRANSMITS WATER FAIRLY RAPIDLY; IN VALLEY BOTTOMS.	
UPPER PART OF 11	▥	THIN BEDS OF HARD LIMESTONE WITH THICKER BEDS OF MARLY LIMESTONE; ON SURFACE OF PLATEAU.	MARLY BEDS TRANSMIT WATER SLOWLY, ESPECIALLY WHERE WEATHERED
11	▨	MARLY LIMESTONE; WEATHERS TO CLAY AND CALICHE; ON EDGES OF PLATEAU.	
3, 10	▧	ALTERNATING BEDS OF HARD LIMESTONE AND MARLY LIMESTONE; ON UPPER SLOPES AND BORDERING LOWER VALLEYS.	
1, 2, 4, 5, 6, 7, 8, 9	□	HARD LIMESTONE IN THICK BEDS JOINTED AND IN PLACES CAVERNOUS; GENERALLY TRANSMITS WATER RAPIDLY; ON STEEP SLOPES AND BENEATH ALLUVIUM.	

————————	HARD SURFACE ROAD
===========	IMPROVED PRIVATE ROAD
- - - - - - - - - -	UNIMPROVED DIRT ROAD
—+——+——+—	RAILROAD
——— . . . ———	WELL-DEFINED STREAM
—— —— ——	WATERSHED BOUNDARY
■	BUILDING
⊙ 4	RAIN GAGE LOCATION NUMBER

54 — STUDY NUMBER
▲ LOGS IN APPENDIX
55 ▲ INCOMPLETE LOGS

} STUDY WELLS





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———	HARD SURFACE ROAD
=======	IMPROVED PRIVATE ROAD
- - - - -	UNIMPROVED DIRT ROAD
—+—+—	RAILROAD
—··—	WELL-DEFINED STREAM
— — —	WATERSHED BOUNDARY
■	BUILDING
⊙4	RAIN GAGE LOCATION NUMBER
54 ▲	STUDY NUMBER LOGS IN APPENDIX — STUDY WELLS
55 △	INCOMPLETE LOGS — STUDY WELLS
SITE 12	RESERVOIR DAM
×	SAMPLE LOCATION
17	SAMPLE NUMBER OF TABLE 3
⚒	CALICHE PIT

FIGURE 6.--DISTRIBUTION OF SURFACE GEOLOGIC MATERIALS ON LOWREY DRAW WATERSHED, SUTTON COUNTY, TEXAS, GROUPED ACCORDING TO THEIR INFLUENCE ON INFILTRATION AND RUNOFF.

DATA BY H.R. BLANK

DRAWN BY J.D. CHILCOAT.

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Map to Accompany "Geology and Groundwater Studies in a Part of the Edwards Plateau of Texas, Including Sutton and Adjacent Counties," ARS 41-103

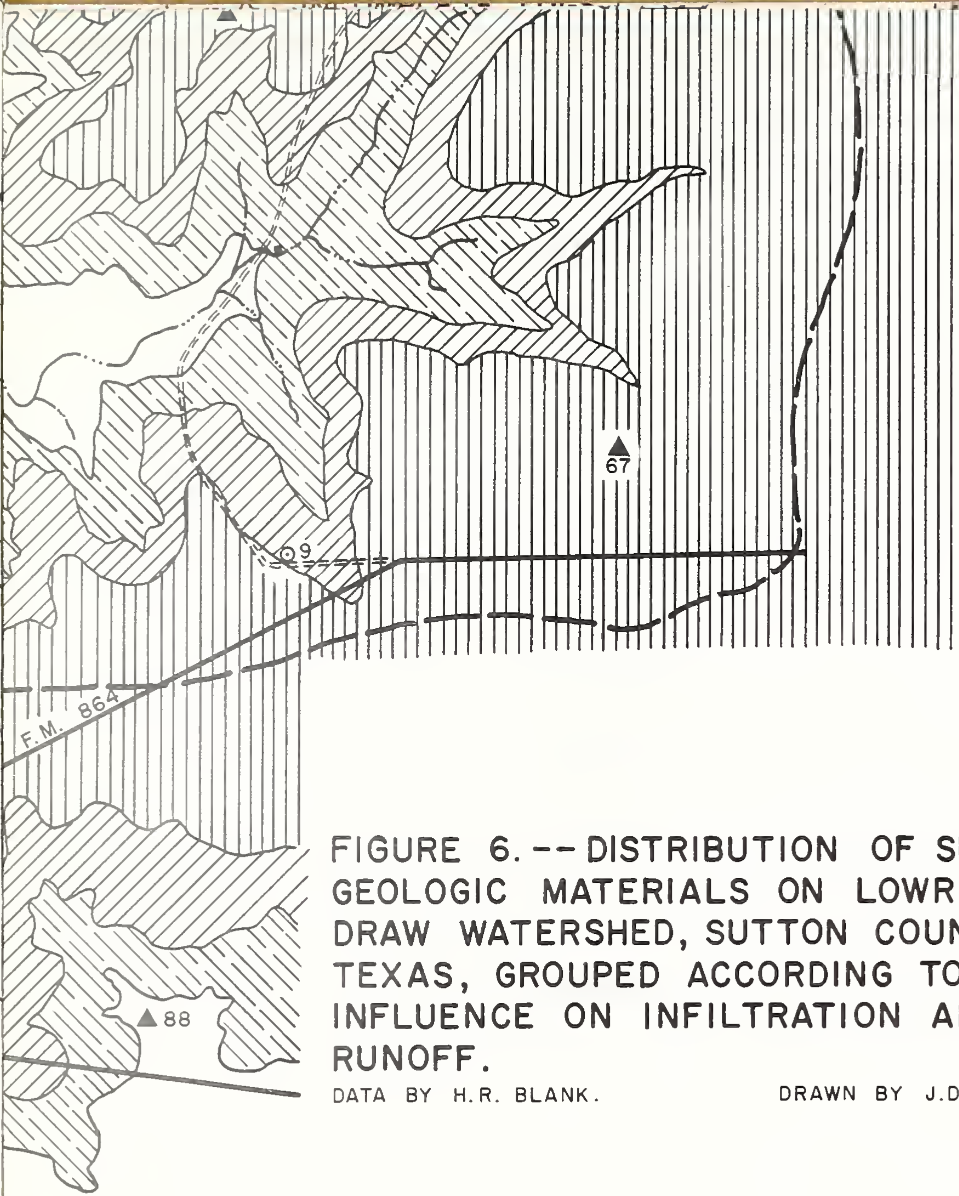
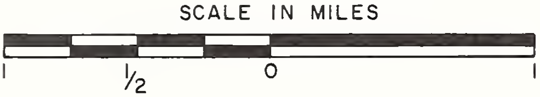


FIGURE 6.--DISTRIBUTION OF SURFACE GEOLOGIC MATERIALS ON LOWREY DRAW WATERSHED, SUTTON COUNTY, TEXAS, GROUPED ACCORDING TO THEIR INFLUENCE ON INFILTRATION AND RUNOFF.

DATA BY H.R. BLANK.　　DRAWN BY J.D. CHILCOAT.



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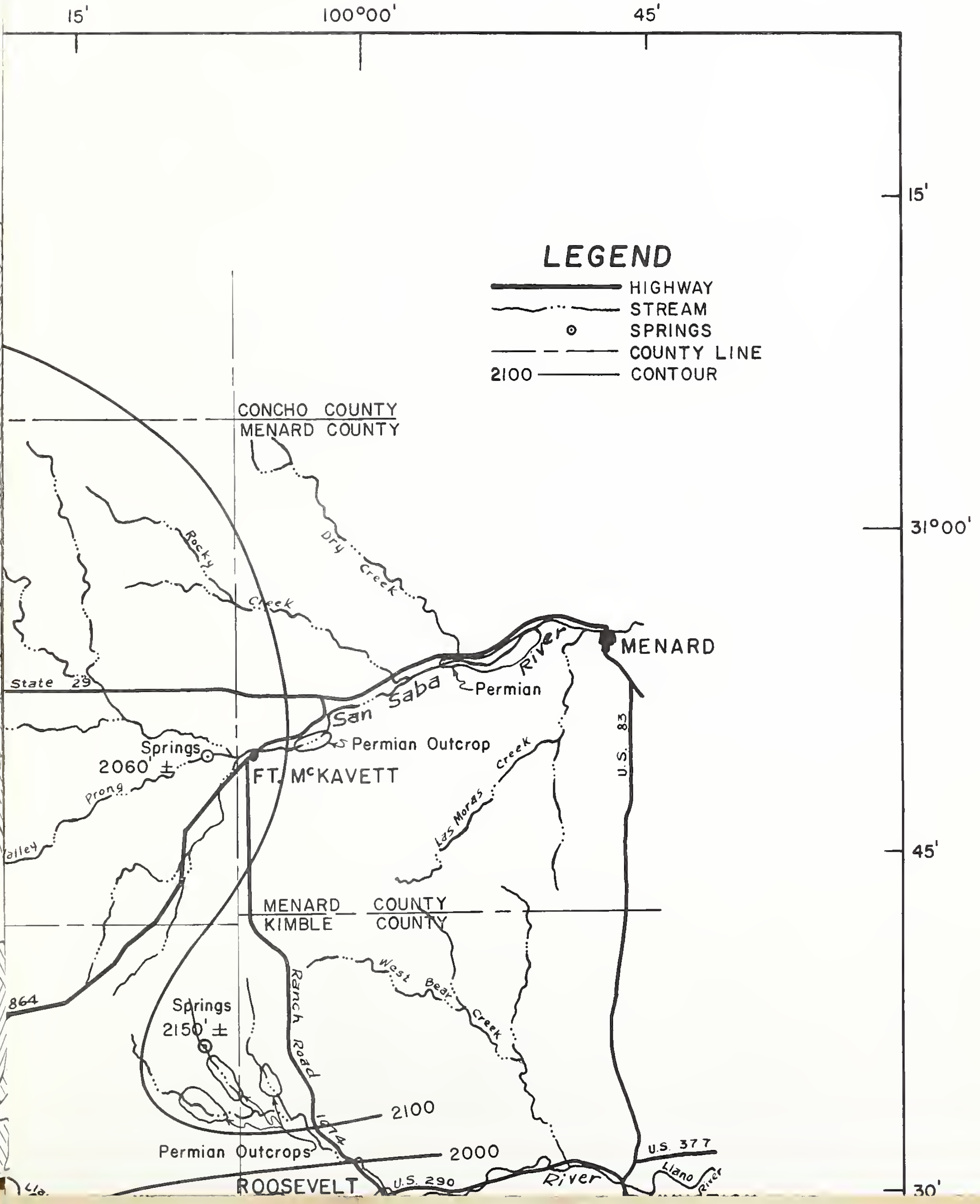
15'
100°00'
45'
15'
31°00'
45'
30'
LEGEND
HIGHWAY
STREAM
SPRINGS
COUNTY LINE
2100 CONTOUR
CONCHO COUNTY
MENARD COUNTY
Rocky Creek
Dry Creek
MENARD
State 29
San Saba River
Permian
Permian Outcrop
Springs
2060' ±
FT. McKAVETT
Prong
Valley
Las Moras Creek
U.S. 83
MENARD COUNTY
KIMBLE COUNTY
West Bear Creek
Ranch Road 1674
Springs
2150' ±
864
2100
2000
Permian Outcrops
ROOSEVELT
U.S. 290
River
U.S. 377
Llano River

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Agricultural Research Service

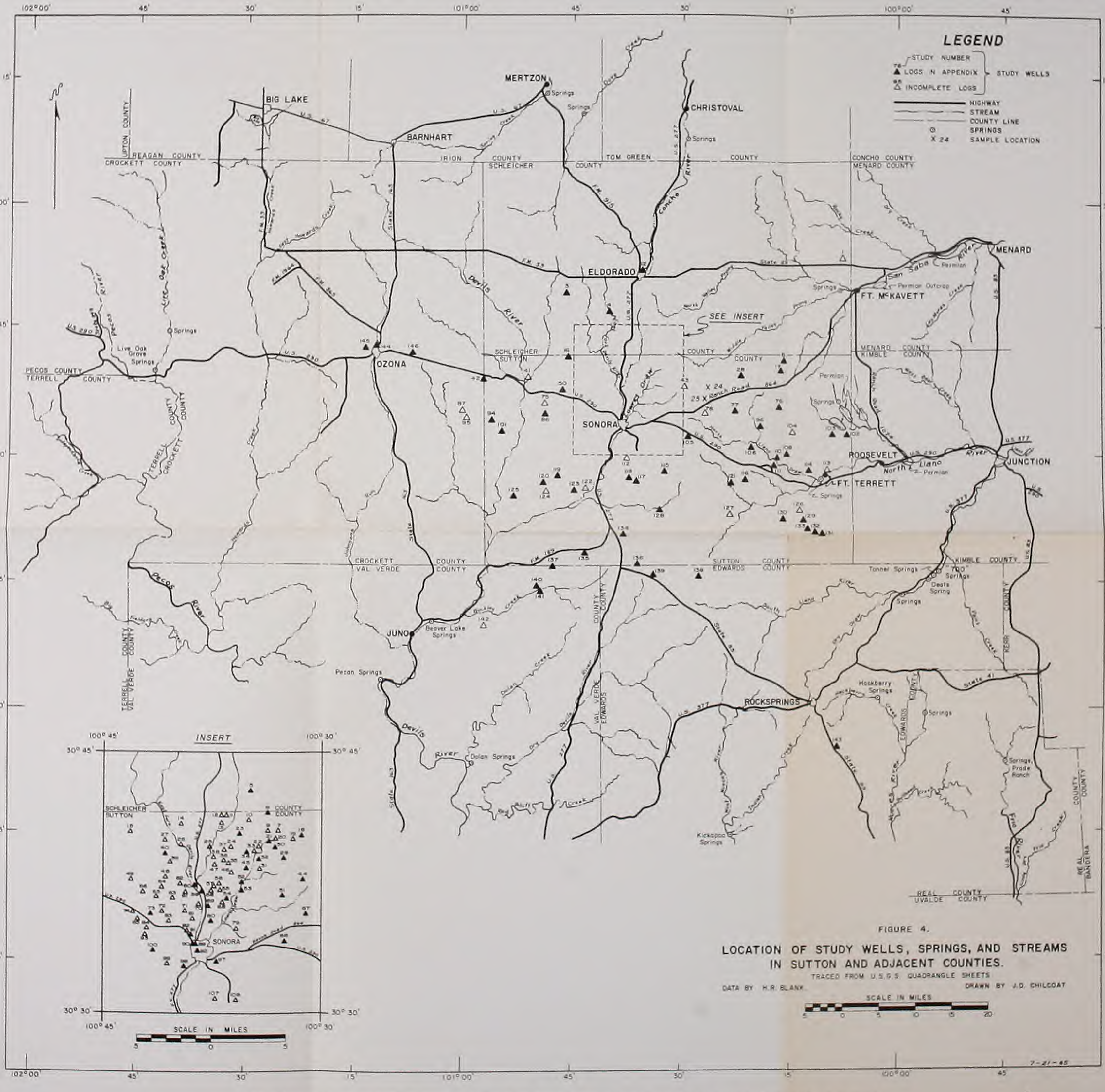

FIGURE 4.

LOCATION OF STUDY WELLS, SPRINGS, AND STREAMS IN SUTTON AND ADJACENT COUNTIES.

TRACED FROM U.S.G.S. QUADRANGLE SHEETS

DATA BY H.R. BLANK. DRAWN BY J.D. CHILCOAT

Map to Accompany "Geology and Groundwater Studies in a Part of the Edwards Plateau of Texas, Including Sutton and Adjacent Counties." ARS 41-103

Geology and Groundwater Studies in Part of the Edwards Plateau of Texas, Including Sutton and Adjacent Counties[1]

3a

by

Horace R. Blank[2], Walter G. Knisel[3], and Ralph W. Baird[3]

SUMMARY

This paper reports the results of a reconnaissance study of the geology and groundwater of that part of the Edwards Plateau, in west-central Texas, centering around Lowrey Draw, an ephemeral stream in Sutton County.

The Edwards Plateau is underlain by resistant limestones of Lower Cretaceous age that are difficult to correlate with the specific formations of this epoch found and named in central Texas. Consequently they have been called the Edwards and associated limestones by other workers and in Edwards and Real counties have been divided by A. T. Long (10)[4] into four zones--A, B, C, and D. Zone C contains several beds of crystalline, friable, spongy, and permeable dolomite or dolomitic limestone, some of which are water bearing.

In the vicinity of Lowrey Draw the exposed rocks consist of hard, nearly pure limestones, which predominate on the valley sides and ridges, and of softer, nodular, marly limestones, which occur on the undissected plateau and in the lower parts of the valleys. Among the purer strata are numerous rudistid reefs. All these rocks appear to belong to zone D and to be of Georgetown age, although the uppermost marly strata may be equivalent to the Grayson formation. The dolomitic beds of zone C have been found in wells.

Although throughout most of the Edwards Plateau the strata appear nearly horizontal, all evidence confirms the structure proposed by Cartwright, in which the Cretaceous beds drape over the hills and sag into the valleys of the buried pre-Cretaceous surface. As a result, in Sutton County they form a broad syncline, plunging gently toward the southwest, with highs toward the northwest and the northeast, and they also probably form a narrower syncline along the South Llano River, southeast of which they drape over the Edwards Arch. In southern and southwestern Edwards and in Val Verde County, all the strata dip more steeply southward and southwestward toward the Balcones fault zone.

Except for the rudistid reefs, most of the limestones of the western Edwards Plateau have little or no primary permeability, but transmit water through their joints and solution openings. The dolomitic beds, however, are permeable and appear to be the most important aquifer. Their occurrence in numerous wells and their outcrops on all sides of the plateau indicate that they probably underlie the entire region, but their permeability varies greatly from place to place. At most places their groundwater is under a slight artesian head, probably due to water standing in the joints of the overlying limestones.

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[1] Soil and Water Conservation Research Division, Agricultural Research Service, in cooperation with the Texas Agricultural Experiment Station and the Texas Engineering Experiment Station.

[2] Consulting geologist and professor of geology, Texas Engineering Experiment Station, Texas A&M University.

[3] Research hydraulic engineers, Soil and Water Conservation Research Division, Agricultural Research Service, at Riesel, Tex.

[4] Underscored numbers in parentheses refer to Literature Cited, p. 25.

The dolomitic beds are recharged by water descending through joints and solution openings of the limestones of zone D. Even the marly limestones apparently transmit water slowly. The water is discharged through numerous springs, which occur throughout the dissected border areas of the plateau wherever the intermittent streams have cut their valleys down to the dolomitic beds or to a joint connecting with them.

At some places a small volume of water, often rich in hydrogen sulfide, is found below the dolomitic beds at the top of "the green shale" (Glen Rose formation) or at the top of the underlying Permian shales. At most places in that part of the Edwards Plateau under consideration, however, if a satisfactory supply of water is not found in the dolomitic beds it will not be found at all.

ACKNOWLEDGMENTS

Work of this kind can be done only with the help of many others. The following men were particularly helpful in the field work: E. B. Keng, Soil Conservation Service; J. A. Letsinger, well driller, Sonora, Tex.; J. D. McAndrew, Soil Conservation Service; R. M. McCarver, city manager of Sonora, Tex.; C. C. Wiedenfeld, Soil Conservation Service; and Wesley C. Young, well driller, Sonora, Tex.

Access to published and unpublished information was freely given by the staffs of the Texas Bureau of Economic Geology, the Texas Water Commission, the U.S. Army Corps of Engineers, and the U.S. Geological Survey.

The logs of numerous oil and gas wells were made available by: Eisner Oil Co., Abilene, Tex.; El Paso Natural Gas Co., Midland, Tex.; Hunt Oil Co., Midland, Tex.; Pan American Petroleum Corp., Midland, Tex.; Penn, Hills and Turner, Midland, Tex.; Shell Oil Co., Abilene, Tex.; Sunray DX Oil Co., Midland, Tex.; and Union Oil Co., Midland, Tex.

INTRODUCTION

This report presents the results of a reconnaissance study of the geology and groundwater of a part of the Edwards Plateau in west-central Texas (fig. 1, p. 4).

The narrow valleys that dissect this plateau are occasionally subjected to severe floods. The region also serves as a source of recharge for important groundwater aquifers that are intensively utilized along its eastern and southern borders.

The Agricultural Research Service is conducting hydrologic studies on the watershed of Lowrey Draw, an ephemeral stream that drains into the East Fork of Devils River at Sonora, Sutton County. Information on the rainfall-runoff-groundwater inter-relationships of this region is needed in connection with the flood-control program carried out by the Soil Conservation Service under Public Law 566. As a part of the hydrologic research, geologic studies were needed to determine any differences in the rocks which might cause differences in the infiltration characteristics of the watershed. Information was also needed regarding the location and characteristics of the springs in the surrounding region through which groundwater originating in or passing under the watershed might be discharged. This enlarged the area of study to include Sutton and ten adjacent counties (fig. 1, p. 4).

In addition to field observations at outcrops and springs, the work herein reported includes the examination of well cuttings and the study of numerous well logs (see appendix pages 27 to 41) obtained from drilling contractors and oil companies. Some of the information and conclusions developed have already been utilized in the groundwater studies reported in ARS 41-100 (8).

GENERAL DESCRIPTION OF THE EDWARDS PLATEAU

The Edwards Plateau is a high region in west-central Texas extending about 300 miles from east to west and about 100 miles from north to south (fig. 1). It is sharply bounded on the south and southeast by the Balcones fault zone, and somewhat less definitely on the east by the Llano uplift (also called the Central Mineral Region). Toward the north it merges into the Low Rolling Plains, and toward the west into the mesas and basins of the Trans-Pecos country. In these last two directions its boundaries are much less distinct.

The plateau proper is a smooth upland surface of very little relief, formed on nearly horizontal limestones of Early Cretaceous age. It has been considerably dissected by relatively deep, narrow valleys arranged in a dendritic pattern, so that probably no more than 50 percent of the region is still a nearly level upland. The valleys are so closely spaced, especially on the southeastern border, that the plateau has been reduced to an area of complexly branching ridges.

Although the plateau has obviously been dissected by running water, only the larger streams have permanent flow under present climatic conditions. These streams are fed by springs that issue from the limestone in the stream beds or at the base of the steep valley walls. Above the springs these main streams and all their tributaries flow only by direct runoff during and immediately after heavy rains. Much of this flow is torrential and of short duration. As a result, many of the stream beds are choked with limestone gravel and boulders and the channels are poorly defined. Many of the valleys are flat bottomed and appear to possess flood plains much more extensive than would be expected from the present streamflow, suggesting a more humid climate in the past. However, even in recent times some floods are reported to have reached from one valley wall to the other.

The undissected portions of the plateau contain many shallow depressions, each of which drains a small surrounding area to form a temporary lake. These lakes dry up after a few days, weeks, or months, partly by evaporation, but probably also by infiltration into the underlying limestone strata. A number of caverns are known to exist in various parts of the region, and probably many others remain to be discovered. Open joints that take in water are common in areas of outcropping rock. Nevertheless, open sink holes leading directly into caverns are rare, although one or two spectacular ones are known.

As the noncarbonate impurities in the limestone consist chiefly of clay, the residual soils of the plateau are heavy clay types. Most of them accumulate calcium carbonate at varying depths and this is especially true over the more easily weathered strata. Wherever erosion is active the soils are rocky, and on the steeper slopes they are very thin or entirely absent.

The annual rainfall decreases rapidly from about 32 inches in the eastern part of the Edwards Plateau to about 18 inches in the western part. In the vicinity of Sonora it is 22 inches. However, the precipitation is unevenly distributed, both in time and in space, especially in the western part of the plateau, so that occasionally one storm may be responsible for half or more of the annual total at a given locality.

Because of the limited and variable rainfall and the large area of rocky soils, very little land is cultivated and nearly all the region is in ranches. Most of the land is covered by native grasses and moderately thick brush, consisting chiefly of mesquite, live oak, juniper cedar, and various cacti.

GEOLOGY OF THE EDWARDS PLATEAU

General Statement

The Edwards Plateau is underlain by resistant limestones of Lower Cretaceous age. Farther east, in central Texas, these limestones have been subdivided into the Trinity, Fredericksburg, and Washita groups, in ascending order, and in each group a number of formations are recognized, as shown in table 1.

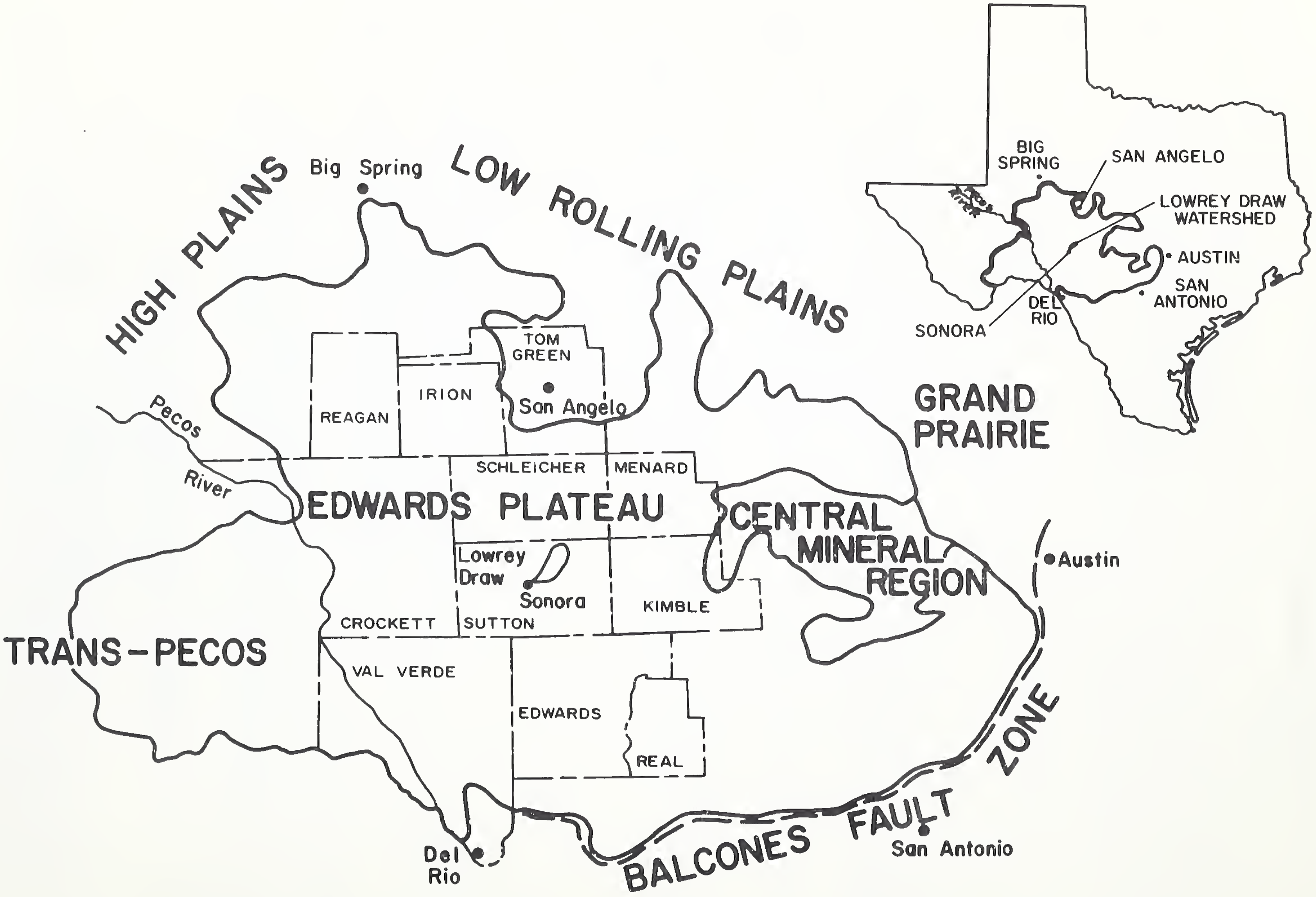

Figure 1.--Location of Edwards Plateau and Lowrey Draw watershed in Texas.

TABLE 1.--Geologic formations of the Edwards Plateau

Epoch	Group	Formation	General lithologic character
Recent and Pleistocene.		Alluvium and colluvium.	Gravel, caliche, and soil in stream valleys.
		UNCONFORMITY	
Lower Cretaceous (Comanchean).	Washita.	Buda limestone.	Hard, gray to brownish limestone--generally thin.
		Grayson (Del Rio) formation.	Clay, marl, and marly limestone.
		Georgetown limestone.	Hard limestone.
	Fredericksburg.	Edwards limestone.	Hard, thick-bedded limestone, containing numerous chert or flint nodules.
		Comanche Peak limestone.	Nodular limestone and marly limestone.
		Walnut formation.	Marl and marly limestone--some hard beds.
	Trinity.	Glen Rose limestone.	Alternating beds of hard limestone and softer marly limestone.
		Travis Peak formation.	"Basement Sands"--sandstone, calcareous shale, and limestone.
		UNCONFORMITY	
Pre-Cretaceous (not exposed).			Shale, sandstone, and limestone.

Pre-Cretaceous Basement

Logs of the study wells (see appendix figure 4) have indicated that in most of Sutton County the Cretaceous beds are immediately underlain by Permian shales and sandstones, but that in the northwestern part of the Edwards Plateau, Triassic strata also are present in the subsurface. Permian (or perhaps Upper Pennsylvanian) limestones appear at the surface in small areas along the San Saba River in Menard County and along the North Llano River and some of its northern tributaries in northeastern Sutton and western Kimble Counties.

"Basement Sands"

The "Basement Sands" of the Cretaceous crop out at the western edge of the Edwards Plateau along the valley of the Pecos River. Here they consist of beds of medium-grained sandstone, mostly calcareous, alternating with strata of marl and limestone. Incomplete information from wells indicates that the sandy strata become more shaly and limy eastward, or else are overlapped by the Glen Rose formation, so that few if any sands free from clay are present in the basal Cretaceous in the region of Sutton County. In the eastern and southeastern parts of the plateau, sandy beds are again present in the subsurface Cretaceous. Here they may include not only the Travis Peak formation but also portions of the Sligo and Hosston formations, although these last two have not been identified west of Kendall County.

Glen Rose Limestone ("The Green Shale")

The Glen Rose limestone crops out in the stream valleys in the southern and southeastern parts of the Edwards Plateau. Its occurrence in Real and Edwards counties has been described by Long (10, 11). In Sutton County wells, it appears as a green or calcareous shale or marl, rather than as a limestone. This material, known as "the green shale" to local drillers, extends in many wells without great change to the top of the underlying Permian strata, although it is somewhat sandy toward the base.

Walnut Formation

Long (10, p. 13) stated that the Walnut clay is probably absent, or at least extremely thin, in Real County and (11, p. 16) that it has not been identified in Edwards County. No new knowledge of its presence or absence in the subsurface of Sutton County was obtained during this study.

Comanche Peak, Edwards, and Georgetown Formations

Difficulty of Correlation

In central Texas the Edwards limestone is notably resistant to weathering and erosion and is the surface formation on most of the higher flat-topped areas, which may be regarded as outlying portions of the Edwards Plateau. Consequently the assumption is easily made that this formation lies at the surface throughout the plateau region. In central Texas the sparingly fossiliferous Edwards is underlain by the less resistant, nodular, and highly fossiliferous Comanche Peak limestone, and east of the Balcones fault zone it is overlain by the Georgetown limestone, also fossiliferous and consequently identifiable.

But with increasing distance westward, all these formations undergo changes in lithologic character, with accompanying changes in the fauna, which also become less abundant. Thus in the central and western portions of the Edwards Plateau it becomes extremely difficult or impossible to distinguish the strata which are equivalent to the formations named and described farther east. For this reason it is becoming common to refer to the Comanche Peak, Edwards, and Georgetown limestones as the "Edwards and associated limestones" (14, p. 16; 10, pp. 12 and 14; 11, p. 16). This designation usually is adequate, because over much of the region these limestones behave as a single hydrologic unit.

Previous Studies of the Plateau Limestones

Detailed geologic studies have not been made over the entire Edwards Plateau. In the southwestern part of the plateau and in Trans-Pecos Texas, a great thickness of lithologically uniform limestone strata, poor in fossils, may be the equivalent of all the Lower Cretaceous formations from the Glen Rose to the Buda, inclusive. This sequence has been called the Devils River limestone (18).

Spice [5], after a detailed study of the geology of a portion of Val Verde County, retained the name Devils River limestone for the hard limestones of that district, in which he was unable to identify the equivalents of the Comanche Peak, Edwards, and Georgetown formations. He found remnants of the Del Rio (now called Grayson) and Buda formations on the higher interstream divides.

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[5] Spice, J. O. Geology of the northwest part of the Dry Devil Quadrangle, Val Verde County, Tex. 1954. Unpublished Master's thesis. Univ. of Tex., Austin.

At Lancaster Hill, on U.S. Highway 290 on the east side of the Pecos River valley in Crockett County, Edson[6] measured and studied the thick sequence of limestones and suggested a tentative correlation of the uppermost beds with the Buda formation.

Curry (3, p. 1,698) recognized that "Considering the broad outcrop over the Edwards Plateau as a whole, it is almost impossible to place a dependable line of demarcation between the Edwards and Georgetown on lithologic grounds alone." However, he placed this contact at the base of a bed containing abundant small oysters of the genus Gryphaea, which is underlain by a more resistant, chert-bearing limestone. Curry believed that this Gryphaea bed could be identified and traced through Kerr, Real, Edwards, Kimble, Sutton, and Crockett counties.

Hughes[7] measured and described a section along U.S. Highway 290 on the hill just southeast of Junction, Kimble County, and considered that the uppermost rocks, forming the plateau surface at this place, belong to the Edwards formation.

Graczyk[8] and Jurik[9] measured and described this "South Junction section" and several additional sections of the Edwards in Kimble and eastern Sutton Counties, accepting Curry's definition of the top of the formation as the base of the Gryphaea bed. At their "Dry Llano section," on U.S. Highway 290 near the eastern edge of Sutton County, this bed is near the top of a hill, but 100 feet or more below the hard limestone forming the surface of the undissected part of the plateau. The limestone of the plateau surface therefore must belong to a formation younger than the Edwards.

Blank found the "Dry Llano section" from directions given personally by Graczyk and Jurik, but was unable to find the Gryphaea bed on the west side of the deep valley crossed by U.S. Highway 290 about 6-1/2 miles west of the Kimble-Sutton County line, although he examined all highway cuts for the next six miles westward, many of which appeared to be at the proper elevation. (This stream is designated as Dry Llano River on the U.S. Geological Survey 1:250,000 map, Sonora quadrangle, but is identified as North Llano River by a sign on the highway, and appears to be named Tenmile Draw on the Texas Highway Department map of Sutton and Schleicher Counties.) Either the strata dip rather sharply westward or the Gryphaea bed is not as persistent as Curry supposed.

In an area in central Texas extending from Tarrant to Williamson Counties the variation in the lithology of the Edwards formation has been described in detail by Lozo (12) and by Nelson (13), but west of the Central Mineral Region detailed work on a similar painstaking scale has been carried out in only a few places.

Long (10, 11) described the Edwards and associated limestones in Real and Edwards counties, and divided the group into four zones: A, B, C, and D. He identified the lowermost, zone A, with the Comanche Peak limestone, but was unable to differentiate the Edwards and Georgetown in zones B, C, and D.

Dolomitic Beds in the Edwards Limestone

Samples from five cable-tool wells, together with the logs of numerous others, indicate that within the Edwards and associated limestones, at about 150 to 180 feet above "the green shale"

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[6] Edson, D. J., Jr. Comanche series, Lancaster Hill, Crockett County, Tex. 1951. Unpublished Master's thesis. Univ. of Tex., Austin.

[7] Hughes, R. J., Jr. A study of the Lower Cretaceous section near Junction, Tex. 1948. Unpublished Master's thesis. Univ. of Tex., Austin.

[8] Graczyk, E. J., Jr. An insoluble residue study of the Comanche Peak and Edwards limestones in central Kimble and eastern Sutton Counties, Tex. 1962. Unpublished Master's thesis. Texas A. & M. College, College Station.

[9] Jurik, P. P. Insoluble residue study of the Comanche Peak and Edwards limestone of Kimble County, Tex. 1961. Unpublished Master's thesis, Texas A. & M. College, College Station.

(marl) that forms the top of the Trinity group in this region, there are one or more beds of dark gray to brownish-gray, fine- to medium-grained, massive, recrystallized limestone that has been partly to completely replaced by dolomite.

Hanna (6, p. 47) concluded from study of various cores from the subsurface Edwards formation of south-central Texas that the "...recrystallized rocks of the Comanchean series vary from limestones to dolomites..." and that "...dolomites are distributed irregularly throughout the series." Nelson (13), in his detailed study of the Edwards formation in McLennan, Coryell, and Bell counties, also found dolomite widely distributed both vertically and laterally in this formation, and even extending down into the upper part of the Comanche Peak formation. He considers that some of the dolomite is primary, but that most of it originated subsequent to lithification. This latter type, which Nelson describes as occurring in a bed from 8 to 10 feet thick (at his locality 14-T-1) 2 miles northwest of Belton, apparently closely resembles the dolomitic beds observed by Blank in the western Edwards Plateau.

In his reports on Real (10) and Edwards (11) Counties, Long describes zone C of the Edwards and associated limestones as consisting chiefly of gray to dark-brown dolomite and dolomitic limestone, and containing considerable chert. The dolomite is generally soft and sugary in texture. Zone C is about 160 feet thick in Real County and about 135 feet thick in Edwards County.

Long's measured section along Texas Highway 55 about 14 miles southeast of Rocksprings was visited by Blank, who subsequently found that the same or very similar dolomitic beds occur in the highway cuts along U.S. Highway 290 southeast of Junction and near Roosevelt, Kimble County. Similar dolomitic beds were also found at most of the springs that emerge around the borders of the western Edwards Plateau. These beds and springs will be described subsequently. Neither Hughes[10], Graczyk[11], nor Jurik[12] mentioned dolomite in their descriptions of the U.S. Highway 290 sections, but this is quite understandable, for by ordinary field criteria the dolomitic beds are difficult to differentiate from the nondolomitic limestones.

The wide distribution of dolomitic beds (appendix fig. 5) suggests that these beds underlie most of the Edwards Plateau included in this study.

The strata of zone C vary considerably in dolomite content. At fresh exposures the highly dolomitic beds are dark gray, entirely crystalline, and of a uniform texture resembling that of fine-grained sandstone or siltstone. In a good light their crystalline nature is evident under a hand lens. They are noticeably friable, and become more so on weathering. Under the drill they usually break down to a "sand," and are often reported as such in drillers' logs. Weathering lightens their color, sometimes changing it to a buff by accelerating the oxidation of their iron; weathering probably increases their concentration of calcium carbonate by accelerating selective solution and reprecipitation. As a result nearly all weathered exposures, and many fresh ones, will effervesce to some extent when cold dilute hydrochloric acid is applied. Thus in some beds the presence of dolomite could be confirmed only by the study of selectively stained thin sections.

As noted by Long, the dolomite seems to weather more readily than the associated limestone beds, and consequently older exposures are full of small caverns, hollows, and secondary calcite.

Nodules of chert, and in some places nearly continuous thin beds, occur in and between the dolomitic beds at most of the outcrops, although the dolomite begins lower in the section than the chert. The chert is of various colors--from black to brown, yellow, and reddish. In the well samples, fragments of gray, bluish, and pinkish chert were recovered with the dolomite cuttings. Much of it is of the same color as the dolomite and is easily overlooked.

Also conspicuous in zone C, especially just above many of the highly dolomitic beds, are thin, flaggy beds of hard, dense, very white, crystalline limestone, only slightly dolomitized. They are rich in microfossils and generally contain chert lenses.

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[10] See footnote 7.

[11] See footnote 8.

[12] See footnote 9.

Microscopic study of fragments and stained thin sections from well cuttings and outcrops shows that all the fine-grained crystalline strata consist of calcite, dolomite, or a mixture of both. The more calcitic beds contain remnants and "ghosts" of microfossils and shell fragments, but the highly dolomitic beds do not. This suggests that in all of them the original limestone has been replaced, in some places by crystalline calcite and in others by dolomite.

The more friable beds, most of which are highly dolomitic, consist of a loose network of euhedral to subhedral rhombs, with considerable interstitial pore space. Larger pores, up to 2 mm. across, occur here and there throughout the mass, and are bordered by relatively large rhombs of either dolomite or calcite. In some specimens the larger voids are partially or completely filled by secondary calcite or by chalcedony. Other specimens are much more compact, having grains finer-textured and anhedral because of mutual interference, thus leaving little or no pore space. Consequently, it is to be expected that the porosity and permeability of the dolomitic beds will vary from bed to bed, and probably also from place to place within the same bed.

After solution in hot hydrochloric acid many of the crystalline beds leave a residue of fine silt, and/or clay, and/or organic matter, as determined quantitatively for exposures along U.S. Highway 290 by Graczyk and Jurik. As a rule, the more calcitic beds contain more clay. The dark gray, highly dolomitic beds invariably contain a small percentage of tarry organic matter.

The dolomitic zone was estimated to be about 120 feet thick at the South Junction section and about 80 feet thick at the Roosevelt section. There is no certainty, especially for the Roosevelt section, that the top of the zone was included in either case. The estimates of thickness were made by aneroid barometer observation and other reconnaissance survey methods.

Grayson (Del Rio) and Younger Formations

Long (10, 11) identified the Grayson (formerly called Del Rio in this part of Texas), Buda, and Eagle Ford formations in outcrops on the higher divides in the northern parts of Real and Edwards Counties. He mapped the Grayson and Buda together on an area of undissected plateau that extends into Sutton County. As discussed subsequently, in the vicinity of Lowrey Draw north and east of Sonora, the undissected portions of the plateau are immediately underlain by strata of marly limestone with a few thin strata of hard limestone. The same is probably true of the extensive undissected area in southern Schleicher County.

The marly beds (unit 11, table 2, page 10) suggest Grayson lithology, and at places the thin, fine-grained limestones associated with them resemble the limestone seen elsewhere in the Buda formation. However, although the marly beds of the plateau near Lowrey Draw are fossiliferous, no specimen even resembling Exogyra arietina, the characteristic and usually abundant fossil of the Grayson formation, was found.[13] Furthermore, rather similar marly beds occur much lower in the section (unit 3, table 2). The evidence therefore is insufficient to enable one to decide whether the Grayson formation is present on the plateau this far north or whether these uppermost beds merely represent a marly facies of the Georgetown. The geologist is forced to take refuge in the grouping "Edwards and associated limestones."

In the area studied no evidence was found of any distinctly different shale or marl, such as might represent the Eagle Ford formation, above the thin, hard limestones just mentioned.

Alluvium and Colluvium

The alluvium on the floor of the larger valleys consists of a heterogeneous mixture of soil, clay, and limestone cobbles and boulders, deposited by past floods, and occasionally rearranged

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[13] Long notes that Exogyra arietina is scarce, though present, in the Grayson of northern Edwards County (11, p. 17) and northwestern Real County (10, p. 18).

Table 2.--Composite geologic section of Lowrey Draw

Probable age		Unit number	Description	Estimated thickness Feet	Height of upper boundary above base Feet
Epoch	Formation				
Recent		13	Colluvium; similar to alluvium and not easily separated from it; contains more angular rock fragments and more caliche; at base of steep hillsides.	0 to 15	
Recent and Pleistocene?		12	Alluvium; heterogeneous mixture of limestone cobbles and gravel with caliche and black, clayey soil; little or no stratification; fills larger valleys.	0 to 100	
			UNCONFORMITY		
Lower Cretaceous (Comanchean)	Georgetown equivalent	11	Marly limestone; thick, easily weathered beds of soft, nodular marly limestone, alternating with thin (less than 1 foot) beds of hard, fine- to medium-grained limestone and silty limestone; the marly beds tan to yellow (where exposed), the hard beds gray to tan; marly beds fossiliferous, containing *Inoceramus*, *Gryphaea*, *Pecten*, *Pachymya*, *Cyprimeria*, *Protocardia*, other clams, three kinds of gastropods, an ammonite, and other fossils.	20	196
		10	Limestone; slabby beds of hard limestone, alternating with thinner beds of softer marly or shaly limestone; the hard beds very fine- to medium-grained, and creamy white to brownish; probably calcarenites and at least partly recrystallized; the softer beds mostly concealed, but litter the ground with small chips.	30	176
		9	Limestone; hard, fine-grained, creamy white to pinkish; beds moderately thick and massive; some beds appear to be partly recrystallized calcarenites.	18	146
		8	Limestone; hard, fine-grained to sub-lithographic, white; contains chert nodules, some of them incompletely silicified; the *upper chert bed*.	3	128
		7	Limestone; hard, fine-grained, white; no chert.	6	125
		6	Limestone; hard, fine-grained, white to tan; contains chert nodules; the *lower or main chert bed*.	3	119
		5	Limestone; hard, medium-grained, partly to wholly recrystallized; generally white, but in places purple in the upper part; reef zone; thick beds, consisting chiefly of elongated-lens biostromes of rudistids and/or caprinids, partly replaced by calcite, with occasional much thicker bioherms of the same; numerous cavities in and between fossils and fragments; much brecciation and healing; also contains a few *Pecten*, *Trigonia*, *Protocardia*; passes laterally into unit 4.	35 to 10	116
		4	Limestone; hard, fine-grained, mottled gray and tan; thick-bedded and massive, with occasional thin marly partings; fossils scarce, but the ammonite *Pervinquieria* found in this zone; passes laterally into unit 5.	10 to 35	81 to 106
	Georgetown, possibly Edwards	3	Limestone; soft, yellow, marly beds up to 4 feet thick, alternating with thinner beds of hard, greenish, sub-lithographic limestone; beds rather lenticular; marly beds fossiliferous, containing small *Gryphaea*, *Pecten*, *Protocardia*, small gastropods, a discoid ammonite (*Engonoceras*?).	44	71
		2	Limestone; hard, medium-grained; apparently somewhat crystalline; white.	17	27
	Possibly Edwards	1	Limestone; hard, sub-lithographic, white; contains numerous well-rounded chert nodules; these are the lowest beds exposed.	10	10
				Base of section	

by those of the present. It contains almost no sand because the rocks of the plateau contain very little quartz, the chert nodules do not shatter easily, and very small limestone fragments dissolve.

Other sources of alluvium are the soil and loose rocks washed down the steep slopes by the often localized torrential rains and deposited in fans and small benches at the edges of the valleys.

Little is known of the thickness of these valley-filling deposits.

GEOLOGY OF LOWREY DRAW AND VICINITY

In the watershed of Lowrey Draw, as in most of the Edwards Plateau region, all the exposed rocks are limestones. These limestones are either fairly uniform, nearly pure calcium carbonate, or nodular, marly limestone with varying amounts of clay. Among the purer strata are numerous reefs consisting of recrystallized and replaced shells and shell fragments. Most of the individual strata are from 6 inches to 4 feet thick, although some of the reefs reach a thickness of 25 feet. Most of the beds appear massive and unlaminated.

The purer limestones are hard, medium-grained to lithographic, and white, weathering to various shades of gray. They crop out in thick beds as cliffs and ledges along the sides of the valleys or Lowrey Draw and its tributaries. Where joints are numerous the ledges may disintegrate into large blocks and boulders.

The reefs occur among the purer strata as lenticular mounds (bioherms) and more widespread strata (biostromes) that may actually be lenses of greater lateral extent. The reefs consist chiefly of the remains of the peculiar pelecypods known as rudistids. Little of the original shell material remains, most of it having been replaced by crystalline calcite. Where the original structure survives the reefs are honeycombed with small cavities up to a few inches across, but in some reefs these spaces have all been filled with secondary crystalline calcite.

The marly beds are softer and less resistant, and are generally covered with soil or talus, except in artificial excavations. For this reason some thin ones may have been overlooked. They are cream-colored to yellow, oxidize to brownish yellow, are very fine-grained, and have a pronounced nodular structure. Some of the thinner ones are lenticular. Fossils, except for rudistids, are more numerous in the marly beds than in the harder limestones, although most of them are poorly preserved.

While in some places hard limestones and marly beds appear to alternate, the marly beds predominate on the undissected plateau and also in the bottoms of the larger valleys, whereas the hard strata predominate in the valley sides and ridges, almost to the exclusion of the marly type.

Although no exact measurements of thicknesses were made, the composite geologic section shown in table 2 was put together from observations of outcrops, spillway and highway cuts, and excavations in the bottoms of the reservoirs.

It would appear that most, if not all, of the rocks in this section belong to Long's zone D of the Edwards and associated limestones and are probably of Georgetown age. Several of the marly beds in unit 3 contain small specimens of Gryphaea, but not in the abundance shown in the thick marly bed considered by Curry (3), Graczyk[14], and Jurik[15] as the base of the Georgetown formation. Prominent chert like that common in the Edwards appears in unit 1. A poorly preserved discoid ammonite found in unit 3 in the southern outskirts of Sonora was tentatively identified by Dr. Keith P. Young of the University of Texas as belonging to the genus Engonoceras, suggesting Fredericksburg (Edwards) age. However, the good specimen of the ammonite Pervinquieria found in unit 4 at the floodwater detention structure at site 11 (appendix fig. 6) in Lowrey Draw Watershed is a characteristic Georgetown fossil. All the other identifiable fossil genera found range through several Cretaceous formations.

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[14] See footnote 8.

[15] See footnote 9.

Two observation wells, ARS-1 and ARS-2 (shown as study wells 52 and 53 near the center of appendix fig. 6), were drilled in 1962 by cable-tool methods on the east side of the valley of Lowrey Draw to depths of 327 and 321 feet, respectively. The logs and samples from these wells indicate that they encountered the chert-bearing limestone of unit 1 (table 2) at about Depth 96 feet (Elevation 2,165)[16]. Below this level only hard limestones with very thin, if any, marly beds were penetrated. At a depth of approximately 243 feet below the surface (Elevation 2,018), chert-bearing, minutely porous, recrystallized limestone and dolomite were found, which apparently correspond to Long's zone C of the Edwards and associated limestones as previously described.

GEOLOGIC STRUCTURE

Western Edwards Plateau

Except for the minor irregularities such as shallow depressions and low knolls, the surface of the undissected portion of the Edwards Plateau slopes gently and regularly from an altitude of about 3,000 feet just east of the Pecos River to about 2,000 feet at the western edge of the Central Mineral Region (see fig. 1). East of the Central Mineral Region, the surfaces of the flat-topped limestone uplands lie in the projection of this same gentle slope toward the Gulf. It was, therefore, originally assumed by most geologists that the plateau is a "stripped plain" whose slope results from and coincides with the dip of the resistant limestone formation that supports it, and that consequently that formation, the Edwards limestone, dips gently and regularly toward the Gulf of Mexico, a little south of eastward (5, p. 52, referring to 7, p. 207).

This explanation is obviously too simple if, as indicated in the preceding sections, formations younger than the Edwards lie at the surface of the undissected plateau in Sutton County and surrounding counties. Either the slope of the plateau is not as uniform as was supposed, or the plateau surface truncates the formations instead of coinciding with their dip slope.

Topographic surveys of sufficient accuracy to enable one to eliminate the first possibility are not yet available. But evidence is accumulating that the dip of the formations is not to the southeast everywhere within the area.

Roberts and Nash (15, p. 21), on the basis of the relatively few elevations available to them, postulated that the Devils and Pecos rivers flow in broad synclines.

Sellards (16, p. 87), discussing the pre-Cretaceous structural features of the Edwards Plateau, mentioned the Edwards Arch, a broad nose or arch in the pre-Cretaceous rocks, extending southwestward from the Llano uplift and recognized chiefly from wells in the northeastern part of Edwards County.

Cartwright (2) made a study of the structure of the Cretaceous of the Edwards Plateau, apparently based chiefly on well information. He presented contour maps of the pre-Cretaceous surface, of the thickness of the Trinity division, and of the base of the Fredericksburg division. Comparison of these maps "...reveals remarkable similarity of the larger features, and shows clearly that the regional structure of the Fredericksburg is controlled by the topography of the terrane on which it was laid." (2, p. 699). That is, Cartwright believed that as a result of differential compaction and other factors, the Cretaceous strata sag downward into the pre-Cretaceous valleys which they fill. According to his map (2, fig. 3) of the base of the Fredericksburg group (reproduced by permission as fig. 2), the dip of these beds, and presumably of the overlying

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[16] Throughout this report elevations and altitudes are given in feet and referenced to mean sea level elevations. Depths are distances below ground surface unless otherwise specified.

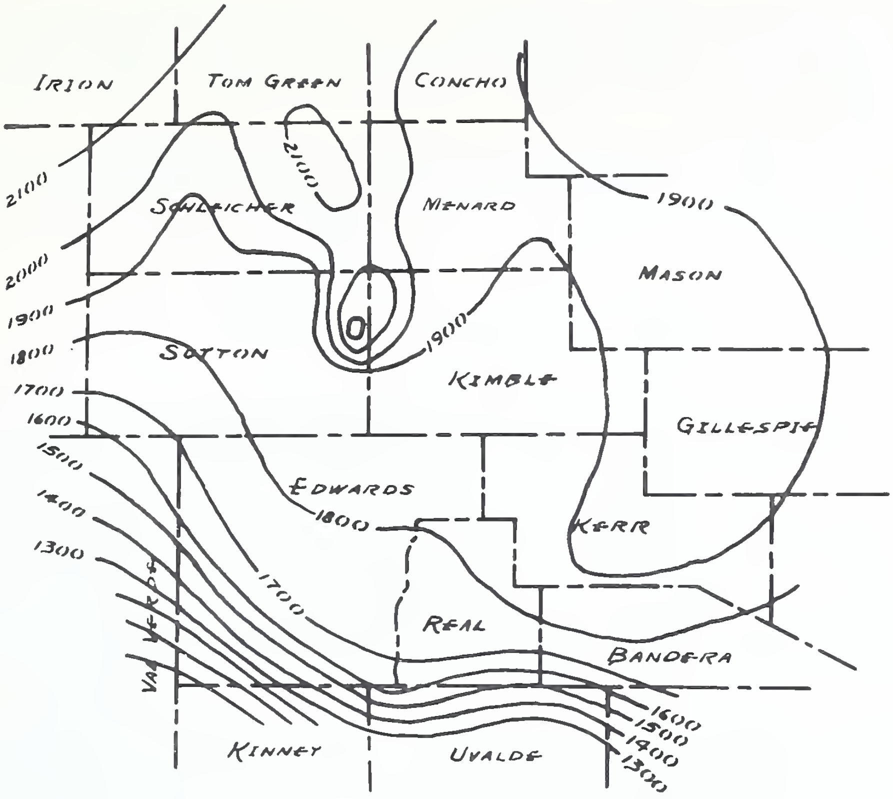

Figure 2.--Contours on the base of the Fredericksburg group with a contour of 100 feet above M.S.L. (Courtesy of Cartwright, L. D., Jr., Amer. Assoc. Petrol. Geol., 1932--Bul. 16:691-700, fig. 3).

Washita strata, should be southwestward in central Sutton County, changing to southward in eastern Edwards County, and steepening greatly farther toward the southwest and south in Val Verde, Edwards, and Real Counties.

This same general trend of the dip is suggested on the "Structural Map of Texas" (17), although contours on the Cretaceous are not shown in Sutton County.

On page 30 of his thesis[17], Spice, after his study of the Dry Devil quadrangle in Val Verde County, states that "...the beds dip uniformly to the southwest with an average dip of 40 feet to the mile, which is somewhat steeper than the average dip of the beds on the Edwards Plateau and also in variance to the regional direction of dip of the Plateau, which in most places is to the south or southeast."

Long (10, pp. 2, 19) said that in Real County the beds dip gently southward toward the Balcones fault zone, and that in the northern part of that county the regional dip of the Edwards and associated limestones is about 10 to 12 feet per mile, increasing to about 20 feet per mile in the southern part. In a later report (11, p. 7) Long stated that in Edwards County the Cretaceous rocks dip generally southward and southwestward at 10 to 12 feet per mile, but that in the northern part of the county they dip northwestward about 3 feet per mile. This suggests that they drape over the Edwards Arch and dip into one of the pre-Cretaceous valleys postulated by Cartwright.

The sample logs of certain wells drilled for oil in Sutton and Schleicher counties (4, 9) indicate dolomite beds at higher elevations than were found in the wells at Lowrey Draw. This indicates a dip toward the southwest, away from the pre-Cretaceous high in the northeast corner of Sutton County. Some of these same logs also indicate the absence of Trinity strata, supporting Cartwright's suggestion that these strata did not cover the entire pre-Cretaceous surface, but filled only the depressions in it.

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[17] See footnote 5.

Blank found dolomite beds, apparently belonging to zone C of the Edwards and associated limestones, at the springs on Spring Creek and Dove Creek in Irion County, at elevations that require a southeastward dip of the Cretaceous in that area. This also is in accordance with Cartwright's map (fig. 2).

Attitude of Strata at Lowrey Draw

In the present investigation attempts were made to determine the strike and dip of the strata exposed in the watershed of Lowrey Draw. The chief difficulty was in finding a stratum that could be identified with certainty at different localities. However, a certain bed in the hard limestones was found to contain numerous chert nodules, which were absent in most of the exposed sequence. Elevations, either by survey or by aneroid barometer, were taken on the top of this bed at its various exposures. Later it was discovered that the chert actually occurs in two separate beds (units 6 and 8, table 2), 9 feet apart vertically. Consequently at some places where this entire interval was not exposed there is some uncertainty as to which bed was used. Other uncertainties arose from the effects of erosion and from the inaccuracy of barometric elevations.

Strikes and dips were calculated from the location and elevation of three points on the same bed. In five such triangles the dips ranged from S. 28° W. to S. 84° W., averaging S. 54° W., and their magnitudes from 1.9 to 8.8 feet per mile, averaging 4.5 feet per mile. The dips are so extremely gentle that the above-mentioned uncertainties greatly influence the results. Nevertheless, it appears significant that all the measurements indicate a dip toward the southwest.

From this study, and from the observations used in compiling table 2, the generalized section shown on figure 3 was developed.

Joints and Faults

Joints are numerous in the hard limestones of Lowrey Draw and the surrounding area. At some places nearly parallel joints occur in bands having definite trends, most of them toward the northeast, but no detailed study of joint trends was made. No displacements were observed along these fractures and no direct evidence of any important faulting was found. However, owing to the difficulty of recognizing individual beds, faults of small throw could easily have escaped notice.

OCCURRENCE OF GROUNDWATER

"Basement Sands"

As mentioned previously, there is some question whether the "Basement Sands" are present under much of Sutton County. The log from a well at the radar station about five miles east of Ozona, in adjoining Crockett County, showed a thin sandy stratum near the base of the Cretaceous, containing a very small amount of water, which was rich in hydrogen sulfide. The electric logs of various oil and gas wells suggest a few sandy strata interbedded with the clays at about this same horizon. In other wells Cretaceous clays appear to pass directly into Permian shales.

ALL EXPOSURES PROJECTED TO THIS LINE.
STRATIGRAPHIC UNITS NUMBERED AS IN TABLE 2.
STRATA OBSERVED AT EACH LOCALITY INDICATED BY SMALL CIRCLE.

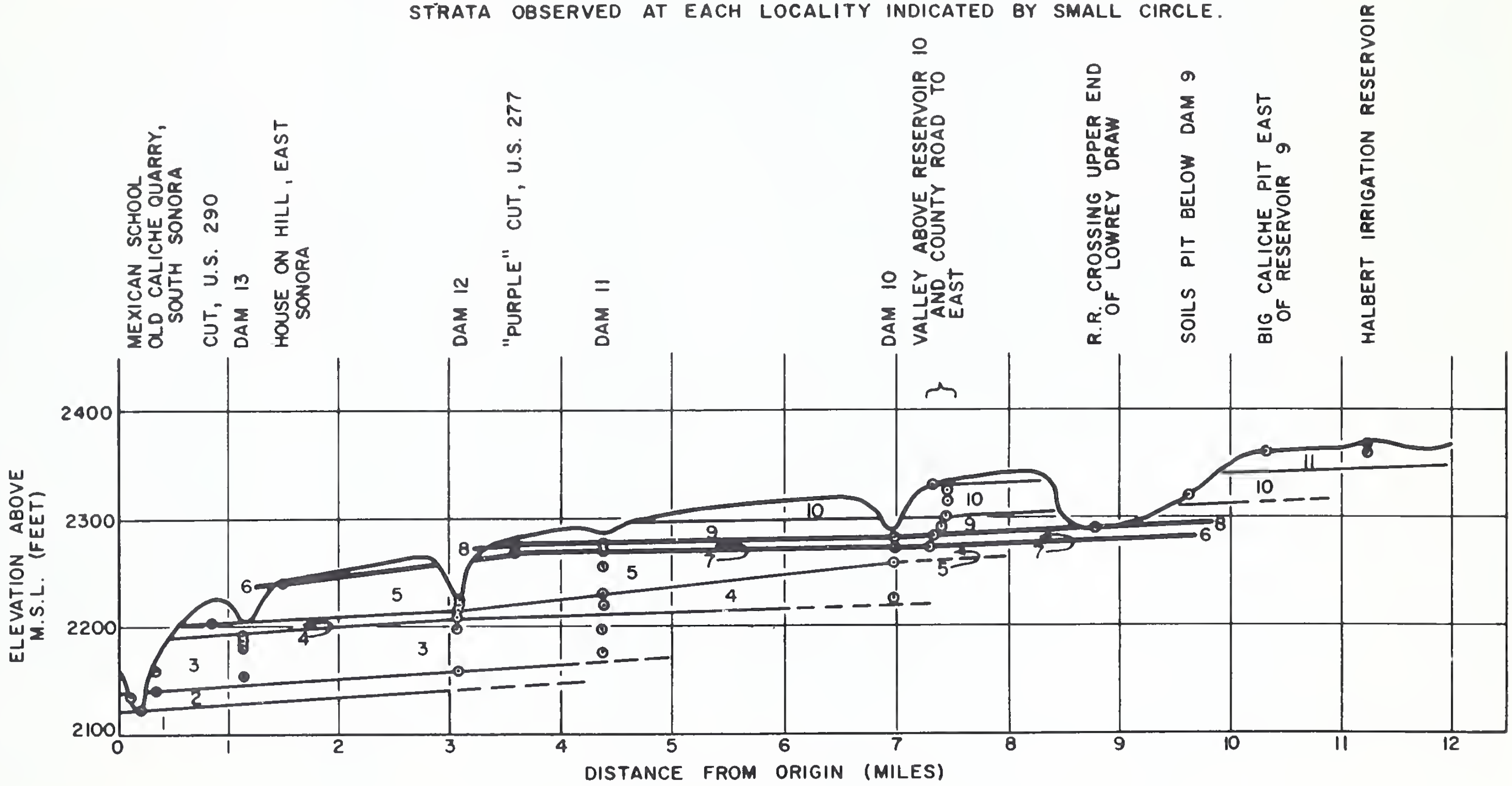
MEXICAN SCHOOL
OLD CALICHE QUARRY, SOUTH SONORA
CUT, U.S. 290
DAM 13
HOUSE ON HILL, EAST SONORA
DAM 12
"PURPLE" CUT, U.S. 277
DAM 11
DAM 10
VALLEY ABOVE RESERVOIR 10 AND COUNTY ROAD TO EAST
R.R. CROSSING UPPER END OF LOWREY DRAW
SOILS PIT BELOW DAM 9
BIG CALICHE PIT EAST OF RESERVOIR 9
HALBERT IRRIGATION RESERVOIR
ELEVATION ABOVE M.S.L. (FEET)
2400
2300
2200
2100
DISTANCE FROM ORIGIN (MILES)
0
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11

Figure 3.--Geologic section through Lowrey Draw Watershed along a line S. 54° W., the average direction of dip.

Long (11, p. 9) states that the "Basement Sands" are not tapped by water wells in Edwards County, although it is probable that small-to-moderate supplies might be obtained from them.

Top of "the Green Shale"

A few wells encounter a little water in a dark, silty, calcareous clay at the top of "the green shale." This horizon may correspond to the Walnut formation, or perhaps to the Paluxy sand, which is the uppermost member of the Trinity group in north-central Texas. In general, water wells are drilled this deep only when sufficient water is not found in the dolomitic beds above. It is the opinion of most of the water-well drillers in Sutton County that once "the green shale" is reached no more potable water will be found.

Dolomitic Beds

It appears that most of the wells in the western part of the Edwards Plateau draw their water from the dolomitic beds of zone C of the Edwards and associated limestones, although this is difficult to establish without samples. Dolomite is very seldom reported as such in drillers' logs; it is more apt to be called gray lime, dark gray lime, or simply "water sand." The most permeable beds are the most friable and crumble readily when drilled, so that loose dolomite grains bailed or washed out resemble true sand in appearance. It seems almost certain that the zone of dolomitic beds underlies the entire western part of the plateau and is the most important aquifer. However, it has not yet been possible to identify the individual beds and to determine their individual extent.

The great variation in yield between different wells, in some cases only a few miles apart, indicates considerable variation in permeability, both in the individual beds and in the zone as a whole.

As far as can be learned from conversation with drillers, at most places the water in the dolomitic beds rises in the well above the level at which it is first encountered. It must be remembered, however, that in either the cable-tool or the rotary method of drilling it is easy to drill some distance past the first inflow of water before detecting it, especially if the inflow is small. Nevertheless, the evidence seems to indicate that at most places the water in the dolomitic beds is under some artesian head.

Hard Limestones of Zone D

The logs of a few wells indicate small quantities of water at elevations well above the dolomitic beds, that is, in the limestones of zone D. However, these seem to be the exception rather than the rule.

RECHARGE TO GROUNDWATER

Recharge Through the Rocks of the Plateau

Permeability of the Rocks (Zone D) Above the Dolomitic Beds

As a whole the rocks immediately underlying the Edwards Plateau possess a rather high permeability, and probably absorb a considerable portion of the rather scanty rainfall. But for most of the exposed rocks--those which lie above the dolomitic beds--this permeability is due not so much to the presence of intergranular pore space as to joints, cracks, space within and between fossils, and similar openings, many of which have been enlarged by the solvent action of water passing through them. Consequently the permeability is very irregularly distributed and practically unpredictable within any small area.

In spite of the difficulty of predicting the permeability of any particular small area, general differences in the capacity of the rocks at Lowrey Draw to take in water are the basis of the map shown as appendix figure 6.

Permeability of the Hard Limestones of Lowrey Draw

The hard limestones of Lowrey Draw have practically no primary permeability. Many of them are recrystallized and are composed of tightly interlocking grains. Their brittleness, however, makes them particularly subject to jointing and their purity makes them readily amenable to solution by water carrying carbon dioxide. Such waters enlarge both vertical and horizontal joints into less restricted channels and eventually into sizable caverns capable of transmitting and storing large quantities of water. The permeability of the rock formation as a whole depends, of course, on the extent to which such passageways are connected, another factor that is almost impossible to predict or to determine.

The rudistid reefs seem originally to have had innumerable spaces, ranging from tiny pores to openings 2 or 3 inches across, between the shells and broken fragments of which they are composed, as well as cavities within the shells themselves, although some of these openings were partly or completely filled with calcium carbonate sand or mud. Recrystallization seems to have reduced this initial pore space by the formation of calcite crystals within the openings, although in some reefs enough of them remain unfilled to form "honeycomb rock."

Permeability of the Marly Limestones

In the nodular, marly limestones innumerable concentric cracks surround the nodular structures; on inspection these cracks seem too tight to transmit much water. Nevertheless, these beds appear to transmit water slowly, especially where they are unweathered, even though their clay content suggests that they might be expected to swell when wet and thus prevent the passage of water altogether.

Weathering of the marly limestones removes some of the calcium carbonate and thereby increases the clay content of the residual decayed rock and soil. Thus the marly beds on and close to the surface of the plateau are the least permeable of all the strata in the vicinity of Lowrey Draw. It appears that the bottom of most of the temporary lakes consists of these marly limestones; many of the depressions occur where an overlying thin layer of hard limestone has been "punctured" and removed by solution. As the water in the shallow lakes disappears some of it must seep slowly downward through the marly limestone, but much of the loss seems to be due to evaporation, which may be increased by capillary movement of the water into the surrounding fine-textured soil, in effect enlarging the evaporation surface. The thick marly beds of unit 11 (table 2), which occur just beneath the plateau surface in this vicinity, cannot be very permeable, for the slight puddling incidental to the excavation of ranch "tanks" (ponds) in these beds enables the "tank" to hold water for several weeks or even months.

The marly limestones found in unit 3 of the sequence shown in table 2 are exposed only in the lower parts of the excavations for reservoirs 11, 12, and 13 (fig. 6) along Lowrey Draw and in some old caliche pits in the southern edge of the city of Sonora. They are interbedded with hard limestones, and none of the individual marly beds is as thick as some of those in unit 11, table 2, which immediately underlie the plateau. The analyses in table 3 show that these lower marly beds contain considerably less clay than do those just under the plateau surface and consequently are probably much less effective in retarding the descent of the gravitational water. They probably underlie the alluvium in some of the valleys.

Table 3. Insoluble residues[1/] in limestones of Lowrey Draw and vicinity

Sample No.[2/]	Location	Unit of table 2	Elevation above M.S.L. Feet	Character	Stratigraphic position	Insoluble residue Percent
1	Just E. of angle in county road, E. side of watershed.	11	2,347	Hard limestone, slightly weathered.	Bed A; thin limestone bed on surface of plateau; much broken.	4.41
2	Same as sample 1.	11	2,339	Marly limestone.	Bed B; nodular marly limestone at side of pond.	13.79
3	Caliche pit at angle in county road, E. side of watershed.	11	2,331	Marl.	Bed C; marl in bottom of pit.	24.50
4	N.W. of angle in county road, E. side of watershed.	10	2,331	Hard brown limestone.	Bed D; ledge at top of slope.	2.69
5	S. slope of valley of tributary to reservoir 10.	10	2,322	Hard limestone.	Bed E.	1.94
6	Same as sample 5.	10	2,314	Hard limestone.	Bed G.	0.55
7	Same as sample 5.	10		Chips of limestone from soil.	From weathering of a softer bed between beds G and H.	1.21
8	Bottom of valley of tributary to reservoir 10.	9	2,291	Hard white limestone; looks pure.	Bed L; ledge at side of stream channel.	0.27
9	Downstream from sample 8.	6	2,274	Hard limestone containing chert.	Bed O; lower chert bed; some chert included in sample.	8.98
10	Spillway cut; S. end of dam 12.	3	2,200	Marly limestone.	Probably upper part of unit 3.	5.02
11	Lowest ledge exposed in reservoir 13.	3	2,154	Hard limestone.	Thin beds of hard limestone in unit 3.	0.09
12	Lowest ledge exposed in reservoir 13.	3	2,160	Hard limestone; tan, lithographic.	Thin beds of hard limestone in unit 3.	0.83
13	Lowest ledge exposed in reservoir 11.	3	2,176	Hard limestone; tan, lithographic.	Thin beds of hard limestone in unit 3.	2.00
14	Spillway cut; S. end of dam 13.	3	2,183	Marly limestone.	Probably upper part of unit 3.	2.42
15	Highway cut, U.S. 290, 1/2 mile E. of Sonora.	5	2,210	Hard limestone; medium-grained, white, partly crystalline.	Rudistid reef; dense material between large fossils.	0.39
16	Base of overflow apron, N. spillway dam 11.	3	2,198	Nodular marly limestone; fossils.	Probably middle part of unit 3.	2.96
17	Highway cut, U.S. 277, 3 1/2 miles N. of Sonora.	3		Nodular marly limestone.	Probably upper part of unit 3.	2.70
18	Soils pit 2, below dam 9; depth 38-40 inches.	10	2,316	Hard lithographic limestone; weathered.	Probably a hard bed of unit 10.	4.74
19	Soils pit 1, Joe Logan ranch; depth 64 inches.	11		Hard, silty limestone; tan.	Thin hard bed in unit 11, on plateau.	7.53
20	Soils pit 1, Joe Logan ranch; depth 66-78 inches.	11		Marly limestone; yellowish.	Marly bed of unit 11, on plateau.	17.41
21	Floor of big caliche pit E. of dam 9.	11		Marly limestone; yellowish.	Marly bed of unit 11, on plateau; 6 ft. below surface.	19.25
22	S.E. corner big caliche pit E. of dam 9.	11		Hard, silty limestone; tan.	Thin hard bed of unit 11, on plateau, 2 ft. below surface.	6.82
23	Ditch on E. side of big caliche pit E. of dam 9.	11		Blue clay; slightly calcareous.	Thin clay bed in marl of unit 11; 6 ft. below surface.	94.65
24	Trench E. of old irrigation reservoir, Halbert ranch; highest part of plateau.	11		Nodular, marly limestone; yellow.	Marly bed in upper part of unit 11; 9 ft. below surface.	17.22
25	Caliche pit W. of playa lake on F.M. road 864, Halbert ranch.	11		Nodular, marly limestone.	Marly bed of unit 11; 7 ft. below surface.	18.82

[1/] Residue insoluble in dilute HCl. Insoluble residue dominantly clay. Particle-size analyses not made.

[2/] Analysis: Samples 1-11 analyzed by H. R. Blank; samples 11-25 analyzed by E. J. Graczyk, Jr. Location: Samples 1-9 collected from successive strata along line shown on fig. 6; samples 10-23 collected at locations shown by number on fig. 6; samples 24-25 collected at locations shown by number on fig. 2.

Recharge through Stream Beds and Valley Flats

The limestone gravel that chokes many of the stream channels is extremely permeable, and many of the flash floods resulting from local heavy rains disappear into it after flowing a few miles. How much of this water actually reaches the main body of groundwater depends, of course, on the permeability of the bedrock underlying the alluvium. Water may enter the alluvium faster than it can penetrate the rocks below, and thus at times considerable water may be stored in the alluvium as a perched water table. No direct observations were made, however, and little is known of the actual situation.

Recharge through Sinkholes

As already mentioned, open sinkholes are rare on the Edwards Plateau, and as far as the authors of this publication are aware, scarcely any of them are located where they receive much surface drainage. Their total contribution to recharge must be small. Most of them are of the type known as cenotes, which are formed by stoping from a cavern below. The largest and most spectacular, the Devils Sinkhole a few miles northeast of Rocksprings, opens directly onto a flat plateau.

Smaller openings partly filled with rubble may be more abundant and are much less conspicuous. A few of these were uncovered in the excavations at flood-detention reservoir sites 10 and 11 (appendix fig. 6). Flow into such openings accounts for most of the rapid loss of water from these reservoirs during periods of storm runoff. Such openings have also been found above the present stream level. Some of them are large enough for a man to enter for a depth of a few feet.

DISCHARGE OF GROUNDWATER THROUGH SPRINGS

Most of the natural discharge of the groundwater in the Edwards Plateau takes place through the numerous springs that rise in the valleys that cut into its borders. If the detention reservoirs recently constructed on the watersheds of Lowrey Draw and the East Fork of the Devils River cause any substantial increase in the recharge to the groundwater, this increase may be reflected in an increased discharge through the springs. For this reason an attempt was made to locate and examine the springs representing the highest level of groundwater discharge in all the valleys surrounding the Lowrey Draw project (appendix fig. 4).

Spring Creek, Irion County

On Spring Creek about two miles southwest of Mertzon, strong springs issue from fissures in the limestone that forms the bed of the creek. The water rises under artesian pressure sufficient to form mounds in the pool about 6 inches high. Very rough estimates on two occasions indicated a flow of between 10 and 20 cubic feet per second from four springs. The altitude, estimated from aneroid barometer readings, is about 2,200 feet.

On the steep hillside immediately above the springs, friable dolomitic beds, alternating with harder limestones, are exposed for a total thickness of about 60 feet. The highly dolomitic beds here have weathered to a buff color rather than the dark gray seen in recent highway cuts. Chert is prominent only in the uppermost beds, which suggests that the springs are emerging from near the base of the dolomitic zone C.

According to Mr. William Simms, county agent, these springs did not fail during the drought years of the 1950's, and additional discharge appears at a higher elevation on the hillside after heavy rains. This supports the supposition that the springs are fed from the main water-bearing stratum.

Very much smaller springs, which produced a barely perceptible flow in the creek in August 1961, appear in Spring Creek about one-half mile upstream from the principal springs.

Dove Creek, Irion County

A large spring gives rise to the permanent flow of Dove Creek in the Schreiner (formerly Wintherbotom) Ranch about 6-1/2 miles southeast of Mertzon. The water flows from beneath thick ledges of white limestone, located just below the ranch house, which are similar to those at the springs on Spring Creek. The water shows no evidence of being under artesian pressure, although it may be. A rough estimate of the flow in August 1961 is about 20 cubic feet per second. The altitude is about 2,162 feet.

At these springs, only about 10 feet of limestone is exposed, but approximately one-quarter of a mile downstream the buff, friable, dolomitic beds overlying the white limestone appear on the side of the valley. Only about 25 feet of the dolomitic section is exposed--not enough to reach the prominent chert-bearing ledges found at Spring Creek. This seems to be another instance of water emerging from the base of the dolomitic zone.

South Concho River

Strong springs rise under pressure through joints in white, flaggy limestone in the bed of the South Concho River about one-eighth mile upstream from the ranch house at the Head-of-the-River ranch, about 3 miles north of the Schleicher-Tom Green county line. Their altitude, estimated from aneroid barometer readings, is about 2,071 feet. Mr. Crosby, the ranch foreman, says that after heavy rains additional springs break out farther upstream and flow for several days.

Tan-colored, friable dolomite, without chert, occurs as ledge and boulders in the stream bed just upstream from the springs. Other dolomitic ledges occur still farther upstream, but the valley contains much alluvium and a continuous section is not exposed. Nevertheless, it appears that here also the springs emerge at the base of the dolomitic zone.

San Saba River

A spring on the C-B Ranch is the source of the permanent flow of the San Saba River about 1 mile west of the Schleicher-Menard county line at Fort McKavett. Another spring flows into the river about one-half mile east of the first. The vegetation suggests other small seeps and springs in the vicinity. The altitude here is estimated to be about 2,060 feet.

Two beds of tan-colored, fine-grained, uniform dolomitic limestone, each about eight feet thick, are present on the south bank of the river downstream from the uppermost spring. They are harder and more calcareous than those on the South Concho River, and are overlain by the hard white limestone. No chert can be observed. Here again the springs emerge at a level no higher than the top of the dolomitic zone.

North Llano River

Near the eastern border of Sutton County, permanent flowing water first appears in the North Llano River at Fort Terrett. The water emerges from gravel and boulders in the stream bed, and thus gives no evidence of artesian flow. A short distance upstream is a permanent quiet pool about one-third of a mile long, which itself may be spring fed. The altitude of the uppermost flowing water is estimated to be about 1,972 feet; that of the pool may be a foot or two higher.

A cliff 60 to 75 feet high on the south side of the upper pool consists of beds of gray to dark gray dolomite and dolomitic limestone, some of which contain chert nodules, alternating with a few beds of white limestone.

South Llano River

A very considerable flow in the South Llano River originates in the "700 Springs" (E-4)[18] just south of the Kimble-Edwards county line. Water seems to emerge from the alluvium at many places over the valley floor. On the Tanner property on the northwest side of the valley, a little higher than the main river and separated from it by a ridge of alluvium, a strong spring (E-3) issues from the rock at the foot of the bluff. Its altitude was estimated to be about 1,891 feet. According to Long's Edwards County report (11), its flow was measured as 4,200 gallons per minute in 1939. The water flows out quietly with no evidence of artesian pressure.

On the same side of the valley, on the Deats Ranch about one-half mile farther upstream, a smaller spring (E-10) flows from under a 2-foot ledge of hard limestone or dolomitic limestone at an altitude of about 1,894 feet. Spongy, dark gray dolomite crops out in the river bed about 6 feet below it. Its yield was measured as 188 gallons per minute in January 1939 (11, p. 47).

Some water flows in the South Llano River for several miles farther upstream. The highest seepage originates just below the crossing of U.S. Highway 377, at an altitude of about 1,950 feet. At the highway crossing the bed of the river is formed by a thick stratum of dark gray, spongy dolomite.

Hackberry Creek, Edwards County

At a point on Hackberry Creek on the Gilmer Ranch about 9 miles east of Rocksprings, strong flows of water issue from several small openings beneath ledges of brownish-gray, spongy, fine-grained dolomite. Their altitude was estimated from aneroid readings to be approximately 1,968 feet. These springs are listed as Hackberry Springs (J-46) in Long's Edwards County report (11), which states that their flow was measured as 1,135 gallons per minute in 1939 and 2,580 gallons per minute in 1954.

About one mile farther south, where the much smaller Benskin Springs (J-44) flow from a small ravine, new road cuts on Farm-to-Market Road 335 expose the dark gray, spongy, friable, crystalline dolomite, containing a little chert.

Nueces River

On the Nueces River, flowing water first appears from under ledges in the stream bed on the Peterson Ranch in the northwestern corner of Real County about 15 miles east of Rocksprings. The altitude was estimated by aneroid barometer to be approximately 1,955 feet. The uppermost flow is only about 1 cubic foot per second or less, but it is increased considerably by other springs farther downstream. These ledges were not examined for dolomite when visited by Blank in 1961 because at that time its existence and probable importance were not realized.

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[18] Symbols in parentheses are the designations used for these springs in the Edwards County report (11, table 3 and plate I).

Frio River

Water first appears in the bed of the Frio River at springs on the Prade Ranch in northeastern Real County at an altitude, as judged from the 100-foot contour map, of about 1,900 feet. These springs were not visited during the present investigation, but their location was known from a previous visit.

West Nueces River

On the West Nueces River, flowing water first appears considerably farther south, at the Kickapoo Springs on the James Rudasill Ranch, about 22 miles southwest of Rocksprings. Here the largest spring (R-19) flows from gravel in a small tributary, but several others (R-18?), some showing artesian pressure, rise from joints in the rock in the bed of the main stream. According to the Edwards County report (11, p. 76), the total measured yield has varied from about 1,100 to about 1,350 gallons per minute. The altitude is approximately 1,748 feet, estimated from aneroid readings and the 20-foot contour topographic map prepared by the U.S. Army Corps of Engineers (Indian Creek quadrangle). Blank visited these springs in 1961 but did not examine the rocks for dolomite. According to the Edwards County report the springs issue from "...near the base of the Edwards limestone."

The water from the Kickapoo Springs flows downstream for only 3 or 4 miles and then disappears completely into the gravel and boulders of the stream bed. It must re-enter the underlying limestone. According to the Real County report (10), this behavior is also shown by the Nueces and Frio rivers.

Devils River

The Devils River and its tributaries drain a large area of the Edwards Plateau in Crockett, Sutton, Schleicher, Edwards, and Val Verde Counties. These streams are notorious for dry valleys, flash floods, and gravel-choked channels. Continuous flow appears only in the main stream well into Val Verde County, many miles south of the tributary headings.

It is realiably reported that groundwater formerly emerged in the bed of the Devils River at a depression called Beaver Lake (estimated altitude approximately 1,720 feet), about 3 miles upstream from Juno, Val Verde County, and also near the Juno post office. However, in recent years several wells in the vicinity have been pumped heavily for irrigation, water has ceased to rise in the river bed, and the former lake bed has been filled with gravel by floods.

At the present time (1963) the uppermost springs along the Devils River appear at Pecan Springs on the Hudspeth River-Ranch, about 12 miles downstream from the Juno post office. A substantial flow of water issues from several openings along the base of the rock bluff on the west side of the valley, forming a series of pools which run parallel to the dry main channel, separated from it by a natural levee, for at least a mile before joining it. From that point on the main channel has a permanent flow, which is augmented by numerous small springs along the valley sides. The altitude of the uppermost pools is estimated to be about 1,597 feet.

The steep bluff above the uppermost pool at Pecan Springs exposes a nearly continuous section of more than 400 feet of the Edwards and associated limestones. Dolomitic beds occur near the base, and alternate with more calcareous limestones throughout the lower 200 feet. Only a few beds consist of the friable, spongy dolomite seen at other springs; most of them are hard and difficult to identify as dolomitic in the field. Individual beds range from 1 to 10 feet thick. The lowermost chert occurs at approximately 100 feet above water level, and the lowest rudistids occur at approximately 250 feet above water level. At about 330 feet above the base, a 3-foot bed that is crowded with small specimens of Gryphaea occurs; this may be Curry's bed, which marks the base of the Georgetown. Above this bed all the limestone is more calcareous and no chert was observed.

Blank also examined the rather poorly exposed 200-foot section on the hill on the north side of Beaver Lake, where fossiliferous limestones, some of them marly and with rudistids and pectens, occur about 20 feet above the base of the bluff. Above them are fine-grained to lithographic limestones containing some chert but only a few thin dolomitic beds. The strata here do not resemble those seen at the other springs and may not belong to zone C.

There are other sizable springs farther south and at lower elevations along the Devils River and its tributaries, but they were not investigated because of their distance and inaccessibility. Of particular interest are Dolan Springs, on Dolan Creek about one mile above its mouth. Their altitude as estimated from the topographic map, (40-foot contour, Dry Devil quadrangle, U.S. Army Corps of Engineers) is approximately 1,350 feet, although they are only 17 miles in a southeasterly direction from Pecan Springs at about elevation 1,597. Of Dolan Springs, Spice says on page 25 of his thesis[19]: "...The main aquifer is a rotten, oxidized limestone bed that crops out only a few feet above the bed of the river in this area....There is not just one spring but a series of springs that gush from the porous rock; the total flow was gauged at 3100 gallons per minute in 1939." This description suggests that the aquifer may be a bed of the porous dolomite.

Spice continues: "...Another series of springs issues from under a talus slope along the east bank of Devils River about a mile north of the junction with Dolan Creek. They are probably from the same aquifer that supplies Dolan Springs and is also the main water stratum for wells in the area. These springs were gauged at 12,000 gallons per minute.

'During the severe drought which started in 1949 and has yet to end in 1954, these two series of springs have kept Devils River flowing. Above the Devils River springs, water ceased to flow for the first time in recorded history in July, 1953, but these springs, though diminished, continued to produce enormous quantities of water."

In 1961, Blank followed Johnson Draw, a dry watercourse that passes through Ozona, from that town to its junction with the Devils River below Juno, but found no springs or flowing water.

Pecos River

The Pecos River, a perennial stream, cuts through the Edwards Plateau between Pecos and Terrell Counties on the west, and Crockett and most of Val Verde Counties on the east. Its deep canyon forms a western limit to the groundwater bodies in the main portion of the plateau, which lies east of it. Approximately 60 miles west of Sonora, the Pecos is joined by Live Oak Creek, whose valley is correspondingly deep. In June 1961, water flow was observed in Live Oak Creek coming from alluvium about 7 miles north of U.S. Highway 290; but the absence of water-loving vegetation suggested the lack of perennial water. Two months later the creek was dry at this point. About one mile north of U.S. Highway 290, at an altitude judged to be about 2,100 feet, a grove of large live oak trees on the west side of the creek suggests the perennial presence of shallow groundwater, and clay appears in the stream bed; however, no definite springs were found here. Thus it seems probable that at times Live Oak Creek flows merely by draining the alluvium on the valley floor, and that any discharge in this direction from the groundwater bodies in the limestone plateau to the east takes place mainly by evaporation and transpiration at the live oak grove. As the "Basement Sands" crop out in hillsides only a few miles farther west, it would seem that the clay in the channel of Live Oak Creek probably belongs to that unit, or in any case is well below the horizon of the dolomitic beds.

Howard Draw is a long tributary of the Pecos River that extends from north to south, about 15 miles west of Ozona. It may be suspected that some groundwater emerges in its lower reaches in Val Verde County, but because of the remoteness of that locality this possibility was not investigated.

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[19] See footnote 5.

CONCLUSIONS

Few groundwater data are available for the part of the Edwards Plateau included in this report. The Texas Water Commission and the U.S. Geological Survey, working in cooperation, have published reports on the geology and groundwater of Real (10) and Edwards (11) Counties. Collection and interpretation of well logs, depths to water, records of water level fluctuations, and similar data, are now in progress by these agencies in Crockett, Menard, Schleicher, and Sutton Counties. Their geologists--L. G. McMillion, J. Goodier, and A. Winslow--have been most kind in discussing their information and interpretations with the authors of this report.

The Agricultural Research Service has begun regular measurements of water levels in wells in the vicinity of Lowrey Draw, but this work has not been in progress long enough to yield much information about groundwater recharge and fluctuations. Numerous well logs (See appendix) have been studied in connection with this report, but samples of drill cuttings from only 5 wells have been available to aid in the interpretation. In addition, accurate elevations have been available only in the vicinity of Lowrey Draw; elsewhere very approximate elevations have been obtained by visiting the wells with an aneroid barometer, which generally could be checked at a bench mark only after many hours. But despite their many inaccuracies and uncertainties, it is believed that the data warrant certain conclusions.

Most of the limestones underlying the Edwards Plateau possess little or no primary permeability. It might be expected that most of the groundwater of the region should be due to a secondary permeability in the joints, caverns, and the "honeycomb" rocks of the rudistid reefs. The abundance, distribution, and extent of interconnection of these openings are almost entirely unknown. If they are all connected with one another, they could give rise to one continuous water table throughout the whole plateau; if not, they could form many local water tables, each one independent of the others. If connected openings are very abundant and very permeable in certain strata in contrast to the strata immediately overlying them, artesian conditions could result, and water under pressure might rise in wells and springs in the valleys.

But while such secondary openings are abundant close to the surface, they seem to be much less numerous at depths greater than 100 feet. Most of the larger openings apparently lie above the zone of saturation, and consequently most of them contain water only briefly after heavy rains. For example, in exploration of the extensive Caverns of Sonora, a continuous water table has not been reached, although some persistent pools have been found. The well logs and observations at drilling wells indicate that most of the groundwater is contained in and moves through the permeable dolomitic beds of zone C of the Edwards limestone. The rest must occupy such joints and solution channels as are present in the upper part of this zone or the lower part of the overlying zone D.

The role of the dolomite as the principal aquifer is confirmed by the logs and samples from 5 wells, by strong indications in the logs of 34 others, and by the outcrop of the dolomitic beds at nearly all the springs.

Drillers report that at most wells the water rises from 10 to 70 feet above the point where it is first encountered. This, together with the obvious artesian behavior of some of the springs, indicates that the water is confined in the dolomitic beds under the slight artesian pressure caused by the head of the water standing in the joints of the rocks overlying them.

Figure 5, the contour map of this water-bearing zone, is subject to criticism on many grounds, and can be considered only approximate. In addition to the uncertainties of the well logs and elevations on which it is based, the outcrops show that not one but several porous dolomitic beds occur in zone C through a vertical interval of at least 100 feet. The springs appear to emerge near the base of the zone, but in the interior of the plateau higher dolomitic beds may be water-bearing, and some wells may tap one bed, some another.

Nevertheless, the map shows a striking similarity to Cartwright's map of the base of the Fredericksburg (fig. 2). Thus from one viewpoint the water-well data confirm Cartwright's ideas of the geologic structure of the western Edwards Plateau, or from the other viewpoint, Cartwright's map confirms the hypothesis that most of the groundwater is contained in a particular stratum or zone of strata.

Several anomalies in the distribution of the groundwater indicate its close relation to the geologic structure. The relatively high elevation of the springs on Hackberry Creek and the Nueces River and their much lower elevation along the South Llano River, and the presence of the dolomitic beds at both places, indicate a draping of the strata over the Edwards Arch. The South Llano River appears to flow along the axis of a syncline in the Cretaceous beds, which may account for the greater volume of its springs as compared to those on the North Llano River. Also, there is a great difference between the levels of the highest water emerging on the Nueces River and its tributaries and those of the West Nueces and Devils rivers. Although the presence of dolomitic beds at Kickapoo Springs and Dolan Springs has not been confirmed in this study, the best explanation seems to be that the strike of the formations runs northwest to southeast through southwestern Edwards County, as suggested by Cartwright. It is also very noticeable that the springs on the north side of the plateau emerge at much higher elevations than those on the south. This too is best accounted for by the structural attitude of the dolomitic beds.

The yields of different wells drawing upon the dolomitic beds differ greatly, indicating that the permeability varies greatly from place to place. This variation is well illustrated by the records of study wells 137 and 141, from which samples were examined by Blank. These wells are located about 4 miles apart on the John Cawthorn Ranch in northeastern Val Verde County (appendix fig. 4). Study well 137 produced 25 gallons per minute from the upper 30 feet of the dolomitic zone, whereas study well 141 produced only one-half gallon per minute after it was drilled all the way to the "green shale."

The permeable dolomitic beds are probably kept filled by water descending through joints, sinkholes, and similar vertical channels in the overlying limestones of zone D. In each of these channels, which are of relatively small volume compared to that of the entire rock mass, the water is in equilibrium with the water in all the channels surrounding it, and with which it is hydraulically connected through the dolomitic beds below. In a sense such a system constitutes a water table, but in another sense it is an artesian system, because the rock between the vertical channels is impermeable, and when drilled through will disclose water under pressure that will rise in the hole. Similarly, where an intermittent stream has eroded its valley almost down to the water-bearing dolomitic bed, a joint in the limestone of the stream bed may permit the water to rise and form an artesian spring.

Thus it is quite possible that water will be found in a vertical fissure by a well located at a level higher than the porous dolomitic beds; however, at most wells no water will be found until these beds are reached. If the elevation of the ground surface is known, it is possible to use figure 5 to estimate the depth to which the wells will have to be drilled. However, even when the dolomitic beds are reached, at some places they will not be permeable enough to yield much water. But although a small amount of water has been found at the top of "the green shale" and even at the top of the Permian strata in a few wells, at most places in the western Edwards Plateau if a satisfactory supply is not found in the dolomitic beds it will not be found at all.

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APPENDIX

WELL LOGS

Note: Data on additional study wells are available but were not included in this report due to insufficient information as to location and/or elevation.

WELL LOG - Study No. 2

City of Eldorado - Water Well No. 1
Driller: V. P. O'Harrow
Drilled: 1938
Location: Lat. 39°51'33"N Long. 100°35'48"W
Located near city hall in Eldorado, Schleicher County.
Approximate ground surface elevation 2460 ft. (Estimated from maps.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Surface soil	2	2
Caliche and boulders	6	8
Hard lime layers	42	50
Caliche	2	52
Hard lime	15	67
Hard lime layers in caliche	19	86
Soft lime	16	102
Hard lime layers	5	107
Caliche	3	110
Hard layers and caliche	9	119
Hard lime	25	144
Lime layers and caliche	87	231
Lime and flint layers	5	236
Hard lime layers and caliche	32	268
Hard lime	12	280
Hard gray lime	29	309
Soft gray lime	5	314
Soft lime	8	322
Lime	8	330
Soft lime and flint	5	335
Lime	3	338
Soft mixed rock	6	344
Hard rock	1	345
Soft porous lime; water	4	349
Hard light gray lime	12	361 T.D.

(Static water level, 280 ft. below land surface when drilled. Yield, 400 gallons per minute.)

WELL LOG - Study No. 3

Parker Farm - Water Well (Irrigation)
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1954
Location: Lat. 30°49'09"N Long. 100°45'54"W
N 1/2 Section 202, Block A, HE&WTRR survey, Schleicher Co. About 11 miles SW Eldorado.
Approximate ground surface elevation 2432 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	1	1
Soil and boulders	3	4
Limestone	336	340
Blind	4	344
Chert	4	348
Water sand	12	360
Lime	6	366
Streaks of water sand and lime	34	400 T.D.

(Excellent well. Butane-engine drive turbine pump delivering approximately 200 gpm into irrigation reservoir.)

WELL LOG - Study No. 4

R. D. Johnson Ranch - Water Well
Driller: Wesley C. Young Drilling Co.
Drilled: May 1960
Location: Lat. 30°46'44"N Long. 100°40'08"W
About 1200 ft. from N line and 1600 ft. from W line, NW 1/4 Section 115, Block A, HE&WTRR survey, Schleicher Co. At SCS site No. 1, Dry Devils River.
Approximate ground surface elevation 2335 ft. (SCS Site Map)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	140	140
Brown lime	65	205
Gray lime	65	270
Sand	10	280
Water sand	10	290
Gray lime	15	305
Sand	5	310
Gray lime	90	400 T.D.

Water standing @ 230 ft. (from driller's log)

WELL LOG - Study No. 5

Bryan Hunt (Thompson Estate) - Water Well #3
Driller: Wesley C. Young Drilling Co.
Drilled: January 1959
Location: Lat. 30°43'23"N Long. 100°34'47"W
About 400 ft. from N line and 2500 ft. from W line of Section 38, Block A, HE&WTRR Survey, Sutton Co. About 10 miles NE of Sonora. (Young's Hunt #3)
Approximate ground surface elevation 2400 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	135	135
Gray lime	100	235
Yellow lime	155	390
Gray lime	10	400 T.D.

Water level @ 318 ft. (from driller's log)

WELL LOG - Study No. 6

Water Well for Honolulu Oil Co. - C. T. Jones, Sr. (E. J. Hardgrove, Jr. fee)
Driller: Wesley C. Young Drilling Co.
Drilled: March 1958
Location: Lat. 30°41'37"N Long. 100°15'57"W
NW 1/4 Section 28, Block 5, TW&NGRR Survey, Sutton Co., out Ranch Road 864. About 1 mile S of Sutton-Schleicher county line and 9 miles W of Sutton-Kimble county line. Well is 4-1/2 miles NE of ranch house.
Drilling floor elevation 2275 ft. (Midland Map Co.)
Approximate ground surface elevation 2265 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Lime	30	30
Blind	15	45
Lime	5	50
Blind	7	57
Yellow lime	18	75
Blind	10	85
Yellow lime	188	223
Blind	12	235
Lime	13	248
Water formation	15	263 T.D.

WELL LOG - Study No. 8

Bryan Hunt (Thompson Estate) Water Well #6
Driller: Wesley C. Young Drilling Co.
Drilled: February 1959
Location: Lat. 30°41'57"N Long. 100°33'34"W
About 1320 ft. from S line and 1320 ft. from E line of Section 30, Block A, HE&WTRR survey, Sutton Co. About 10 miles NE of Sonora. (Young's Hunt #4)
Approximate ground surface elevation 2374 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Blind - yellow lime	100	100
Yellow lime	85	185
Blue lime	140	325
Sand and lime streaks	25	350
Gray lime	10	360 T.D.

WELL LOG - Study No. 16

Alice L. Jones - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled:
Location: Lat. 30°41'54"N Long. 100°45'40"W
About 1/2 mile from N line and about 1000 ft. from W line of Section 3, W. J. Thornton Survey, Sutton County. About 10 miles NW from Sonora and about 1/2 mile S of north county line. Windmill well.
Approximate ground surface elevation 2382 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	2	2
Caliche	18	20
Yellow lime	257	277
Water and broken lime	3	280
Gray lime	84	364
Water and broken lime	6	370
Water sand	5	375
Gray lime	21	396 T.D.

WELL LOG - Study No. 17

Cleveland T. Jones, Sr. - Water Well (Headquarters Ranch)
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: November 1961
Location: Lat. 30°40'17"N Long. 100°16'26"W
SE 1/4 of Sec. 44, Blk. 5, TW&NGRR Survey, Sutton County. About 2 miles east from hdq. ranch house. About 25 miles ENE from Sonora. Electric pump.
Approximate ground surface elevation 2293 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	3	3
Gray lime	7	10
Lime and crevices	60	70
White lime	40	110
Blue lime	20	130
Yellow lime	35	165
Porous lime	3	168
Water formation	27	195
Gray lime	5	200
Gray lime and shale	92	292 T.D.

(Well 6 1/2" diam. Yield 30 gallons per minute.)

WELL LOG - Study No. 18

Joe F. Logan - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1959
Location: Lat. 30°40'47"N Long. 100°31'16"W
About 174 ft. from N line and 336 ft. from E line of Section 36, Block 9, TW&NGRR Survey, Sutton County. About 12 miles NE from Sonora and about 2 miles S from N county line.
Approximate ground surface elevation 2358 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	2	2
Caliche	18	20
Yellow lime	90	110
White lime	170	280
Gray lime	40	320
Water formation	25	345 T.D.

WELL LOG - Study No. 21

Surface Hole for El Paso Natural Gas Co.
Thompson No. 1-D
Driller: Wesley C. Young Drilling Co.
Drilled: August - September 1958
Location: Lat. 30°40'15"N Long. 100°33'28"W
SE 1/4 of Section 32, Block A, HE&WTRR Survey, Sutton County. About 10 miles NE of Sonora.
Ground surface elevation 2351 ft. (ARS Survey)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	170	170
Gray lime	51	221
Yellow lime	29	250
Gray lime	45	295
Water formation	13	308
Sandy lime	4	312
Brown lime	58	370
Gray lime	110	480
Gray lime and shale	26	506
Green shale	74	580
Green shale and lime	18	598
Red bed	9	607

WELL LOG - Study No. 23

C. L. Norsworthy & Lone Star Gas Co. - #1 R. M. Thomson
Location: Lat. 30°40'56"N Long. 100°35'28W
1980 ft. from E line and 860 ft. from S line (S 1/2) of Section 67, Block A, HE&WTRR Survey, Sutton County.

Kelly Bushing elevation 2342 ft.

Notes by H.D.H. from Sample Log, courtesy of Penn, Hills, and Turner, Midland, Texas

Partial Sample Log from 0 Ft.

Description	Depth (Ft.)
Slightly porous lime	0-50
Lime, cavernous, slight-fair porosity	80-90
Lime, chert	160-170
Dolomite, chert	170-180
Dolomite, chert	180-190
Lime and dolomite, chert	190-200
Lime, chert	200-210
Dolomite and lime, chert	210-220
Lime, sandy	250-260
Lime, cavernous, slight porosity	270-280
Lime, cavernous, slight-good porosity	280-300
Lime, cavernous, slight porosity	300-310
Dolomite, slight porosity and lime, cavernous	310-320
Dolomite, cavernous, slight porosity	320-330
Dolomite, cavernous, chert	330-340
Dolomite, chert	340-350
Possible Trinity (from log)	500
Top of Permian - San Andres (from log)	660

WELL LOG - Study No. 2B

Southern Crude Oil Purchasing Co. - # 1 Allison - Oil Test
Drilled: January-June 1929
Location: Lat. 30°39'39"N Long. 100°22'08"W
2310 ft. from N line, 330 ft. from E line, Section 44, Block K, GH&SARR Survey, Sutton County. About 12 miles NE from Sonora, about 3 miles S of N county line. (by H.R.B.)

Notes from Sample Log courtesy of Penn, Hills, and Turner, Midland, Texas

Sample Log from 0'

Description	Depth (Ft.)
Porous light gray, buff, and brown, crystalline limestone--some calcite crystals -- water	300
Porous limestone	300-340
Marked "Com.," i.e., base of Cretaceous	555
Gray limestone and shale -- crinoid stems	570
Leonard fusilinids	5B0
Wolfcamp fusilinids	B10
(First shale /gray marl and pyrite/ indicated at Depth 530 -- all above that depth shown as limestone -- no chert mentioned.)	
*******	*******
	4950 T.D.

WELL LOG - Study No. 29

Bryan Hunt (Jas. T. Hunt, fee). - Water Well #14
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1959
Location: Lat. 30°39'20"N Long. 100°32'25"W
About 1300 ft. from E line and 1600 ft. from S line of Section 44, Block 9, TW&NGRR Survey, Sutton County. About 9-1/2 miles NE from Sonora. Farthest SE of the windmills on this Hunt ranch.
Approximate ground surface elevation 2370 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	2	2
Caliche	33	35
Brown lime	B5	120
White lime	120	240
Yellow lime	40	2B0
Gray lime	53	333
Water formation	32	365
Brown lime	11	376 T.D.

WELL LOG - Study No. 30

Bryan Hunt (Thompson Estate) - Water Well #12
Driller: Wesley C. Young Drilling Co.
Drilled: January 1959
Location: Lat. 30°39'57"N Long. 100°33'0B"W
About 4700 ft. from S line and on W line of Section 44, Block 9, TW&NGRR Survey, Sutton County. About 10 miles NE of Sonora. (Young's Hunt #2)
Approximate ground surface elevation 2365 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	135	135
Gray lime and flint	100	235
Water-sand	7B	303
Lime streaks	99	402 T.D.

Water level @ 294 ft. (from driller's log).

WELL LOG - Study No. 32

Bryan Hunt (Thompson Estate) - Water Well
Driller: Wesley C. Young Drilling Co.
Drilled: January 1959
Location: Lat. 30°39'15"N Long. 100°34'10"W
About 900 ft. from S line and on W line of Section 33, Block A, HE&WTRR Survey, Sutton County. About 10 miles NE of Sonora. (Young's Hunt #1)
Approximate ground surface elevation 2344 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil - rock	B	B
Yellow lime	205	213
Blind	5	21B
Gray lime	57	275
Water	B	2B3
Blue lime	62	345
Sand, water	11	356
Gray lime	10	366 T.D.

Water level @ 270 ft. (from driller's log)

WELL LOG - Study No. 34

Water Well for El Paso Natural Gas Co. - Thompson No. 1-C
Driller: Wesley C. Young Drilling Co.
Drilled:
Location: Lat. 30°39'46"N Long. 100°35'00"W
NW 1/4 of Section 34, Block A, HE&WTRR Survey, Sutton County. About 9 miles NE of Sonora.
Approximate ground surface elevation 2270 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Hard yellow lime	40	40
Yellow and white lime	90	130
Yellow lime	40	170
Gray lime (Drilling water @ 170 ft.)	35	205
Water @ 24B-262	57	262
Yellow lime	14	276
Water	5	2B1
Gray lime	19	300 T.D.

WELL LOG - Study No. 40

Water Well for El Paso Natural Gas Co. - Meckel No. 2
Driller: Wesley C. Young Drilling Co.
Drilled: July 1958
Location: Lat. 30°39'43"N Long. 100°40'37"W NE 1/4 Section 124, Block A, HE&WTRR Survey, Sutton County. About 6-1/2 miles N of Sonora and 2 miles W of the Eldorado highway U.S. 377.
Approximate ground surface elevation 2299 ft. (EPNG Co.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
White lime	85	85
Yellow lime	89	174
Gray lime	26	200
Yellow lime (Small trace of water @ 218 ft.)	20	220
Gray lime	66	286
Yellow lime (Water formation @ 306 ft. - not much water)	20	306
Gray and brown lime	54	360 T.D.

WELL LOG - Study No. 42

R. V. Sewell (Mrs. Stella Sewell) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: August 1960
Location: Lat. 30°39'28"N Long. 100°57'14"W NW 1/4 Section 7, Block IJ, GC&SFRR Survey, NW Sutton County.
Approximate ground surface elevation 2275 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	8	8
Limestone	257	265
Water formation	10	275
Limestone	12	287
Water formation	13	300
Limestone	10	310 T.D.

WELL LOG - Study No. 44

Vestal Askew - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: July 1962
Location: Lat. 30°38'10"N Long. 100°31'14"W About 80 ft. from N line and 280 ft. from E line of Section 70, Block 9, TW&NGRR Survey, Sutton County. About 9 miles NE from Sonora. With windmill.
Approximate ground surface elevation 2347 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	3	3
Boulders	7	10
Yellow lime	80	90
White lime	147	237
Gray lime	53	290
Blue lime	40	330
Yellow lime	3	333
Water formation	27	360 T.D.

WELL LOG - Study No. 45

Water Well for El Paso Natural Gas Co. - No. 5 Steen
Driller: Wesley C. Young Drilling Co.
Drilled: July 1958
Location: Lat. 30°38'53"N Long. 100°34'58"W NW 1/4 of Section 11, GC&SFRR Survey, Sutton County. About 6-1/2 miles NE of Sonora.
Ground surface elevation 2266 ft. (ARS Survey)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
White lime	45	45
Yellow lime	97	142
Gray lime (trace of water)	48	190
Yellow lime	26	216
Gray lime	24	240
Water formation (good water)	40	280
Gray lime	20	300 T.D.

Water level at 230 ft. (from driller's log)

WELL LOG - Study No. 50

Mrs. Carrie Simmons - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Location: Lat. 30°38'16"N Long. 100°43'02"W At S edge of N 1/2 of Section 73, Block D, GC&SFRR Survey, Sutton County. NW part of county. S12°E from the house about 7000 ft.
Approximate ground surface elevation 2310 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	2	2
Yellow lime	18	20
Blind	15	35
Yellow lime	105	140
White lime	40	180
Blind	60	240
Yellow lime	14	254
Gray lime	58	312
Water lime	6	318
Yellow lime	19	337 T.D.

Water at 312 ft.

WELL LOG - Study No. 51

Alley McBride Askew - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: September 1959
Location: Lat. 30°37'06"N Long. 100°32'35"W About 1/4 mile from N line and 1/2 mile from E line of Section 74, Block 9, TW&NGRR Survey, Sutton County. About 7 miles NE from Sonora. About 0.6 mile N of house. With windmill.
Approximate ground surface elevation 2324 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	1	1
Caliche	34	35
Yellow lime	85	120
White lime	117	237
Gray lime	71	308
Water sand	4	312
Sandy lime	6	318
Water sand	22	340
Gray lime	10	350 T.D.

WELL LOG - Study No. 52

Agricultural Research Service (Ada Steen Wynn)
Observation Well # 1
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: June 6-14, 1962
Location: Lat. 30°37'54"N Long. 100°35'14"W
1375 ft. from S line and 4850 ft. from W line of Section 12, GC&SFRR Survey, Sutton County. About 6 miles NE from Sonora, Texas.
Elevation ground surface (datum) 2261 ft. (ARS Survey)

Sample Log (by H.R.Blank)

Description	Thickness (Ft.)	Depth (Ft.)
Soil, black, clayey	0.5	0.5
Limestone, tan, fine-grained to lithographic, with a little white marl	23.5	24
Limestone, tan, hard -- no marl	12	36
Limestone, yellowish, with yellow marl, apparently in alternating hard and soft strata	36	72
Limestone, tan, hard, with a little white marl	12	84
Limestone, gray to white, hard, brittle -- considerable mud loss 92 to 96 ft.	12	96
Limestone, gray to white, with numerous pieces dark gray chert (flint)	7	103
Limestone, gray, lithographic, hard, with thin streaks of white marl -- rudistid molds	26.5	129.5
Limestone, white, hard, lithographic, with much brownish-gray chert	6.5	136
Limestone, white, hard, lithographic	11	147
Limestone, gray, hard, granular, somewhat porous -- possibly dolomitic -- most of water and mud lost in crevices 148 to 162 ft.	15	162
Limestone, yellow, fine-grained to lithographic, hard, with red clay and yellow chert -- some water loss in lower part.	42	204
Limestone, very dark gray, fine-grained to lithographic, hard -- silty and possibly dolomitic	21	225
Limestone, white, lithographic, hard	2	227
Limestone, pale yellow, medium-grained, miliolids ls., with a little yellow clay	4	231
Limestone, light gray, lithographic, hard	4	235
Limestone, pale yellow, with a little yellow clay	2	237
Limestone, white to light gray, hard	6	243
Groundwater at 243 ft. depth.		
Limestone, tan to rusty, medium- to coarse-grained miliolids ls. -- disintegrates under drill like sand -- water-bearing	7	250
Limestone, dolomitic, white, hard, and dolomite, tan, in alternating thin strata, with some yellow to gray clay.-- water-bearing.	20	270
Limestone, dolomitic, miliolid, white to light gray, hard,	10	280
Dolomite, light gray to white, minutely porous, alternating harder and softer strata	8	288
Dolomite, brownish-gray, porous, with bluish, white, and pink opaline chert -- water	12	300
Dolomite, gray and brownish-gray, alternating harder and softer layers -- minutely porous to drusy -- water-bearing.	27	327 T.D.

(Water rose to depth 229 ft. overnight.)

WELL LOG - Study No. 53

Agricultural Research Service (Ada Steen Wynn)
Observation Well # 2
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: June 14-24, 1962
Location: Lat. 30°37'49"N Long. 100°35'25"W
755 ft. from S line and 3790 ft. from W line of Section 12, GC&SFRR Survey, Sutton County. About 6 miles NE from Sonora.
Elevation ground surface (datum) 2273 ft. (ARS Survey)

Sample Log (by H.R.Blank)

Description	Thickness (Ft.)	Depth (Ft.)
Soil	0.5	0.5
Limestone, brown	13.5	14
Cavern -- all mud and water lost	8	22
Limestone, brown and white	19	41
Limestone, tan to yellow, with a few streaks of white clay or marl	59	100
Limestone, yellow with some gray ls. and a little clay -- water loss 110-117 ft.	15	115
Limestone, light yellow, with chert	6	121
Limestone, light yellow and gray	5	126
Fractured zone -- no samples -- all water and mud lost	5	131
Limestone, yellow, with some chert	3	134
Limestone, gray and light yellow -- considerable water loss from 146-150 ft.	16	150
Limestone, gray, with chert, much water loss	17	167
Limestone, gray, hard, much water loss	23	190
Limestone, gray, yellow, and brown -- all water and mud lost 207-209 ft.	19	209
Limestone, very dark gray, fine-grained to lithographic, with a little gray clay and a few shells	36	245
Limestone, pale gray to rusty, lithographic	7	252
Limestone, white and light gray, lithographic, with a little drusy calcite	3	255
(Groundwater at depth 254.5 ft., possibly in cracks)		
Limestone, dolomitic, fine-grained, hard	3	258
Limestone, dolomitic, pale gray, crystalline, minutely porous, resembling tufa	9	267
Limestone, dolomitic, pale gray, and dolomite, darker gray, spongy, in alternating beds -- freely water-bearing	18	285
Limestone, white, hard	2	287
Limestone, tan, miliolid, disintegrates like sand -- a few streaks of white clay -- in general water-bearing	11	298
Dolomite, white and gray, minutely porous, resembling tufa, with a little bluish opaline chert -- probably water-bearing -- mostly soft.	23	321 T.D.

(Water rose to depth 241 ft. overnight.)

WELL LOG - Study No. 54

W. A. Miers - Water Well
Driller: Wesley C. Young Drilling Co.
Drilled: 1961
Location: Lat. 30°37'00"N Long. 100°36'15"W
Located at new private reservoir on E side of County road between SCS flood detention reservoir site Nos. 11 and 12, Lowrey Draw. About 3-1/2 miles NE of Sonora, Sutton County.
Approximate ground surface elevation 2220 ft. (Estimated)

Information from Wesley C. Young, Driller

Description	Depth (Ft.)	Elev. (Ft.)
Ground surface	0	2220
Top of aquifer	270	1950
Total depth	310	1910

WELL LOG - Study No. 59

Water Well for El Paso Natural Gas Co. - Davis 1-A
Driller: Wesley C. Young Drilling Co.
Drilled: May 1958
Location: Lat. 30°37'26"N Long. 100°38'09"W
NE 1/4 Section 17, EL&RRRR Survey, Sutton County. About 7 miles N of Sonora on Eldorado highway. Well E of highway.
Approximate elevations: Kelly bushing 2287 ft. (EPNG Co.)
Ground surface 2276 ft. (EPNG Co.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	45	45
White lime	93	138
Yellow lime	24	162
Gray lime	18	180
Yellow lime (trace of water @ 185 ft.)	60	240
Water (good water)	42	282
Gray lime	18	300 T.D.

(Water level @ 240 ft. from driller's log.)

WELL LOG - Study No. 60

El Paso Natural Gas Co. - No. 3-B Meckel
Hole for surface casing for gas well
Driller: Wesley C. Young Drilling Co.
Location: Lat. 30°37'54"N Long. 100°38'33"W
1320 ft. from S line, 1320 ft. from E line of Section 14, GC&SFRR (J. L. Davis) Survey, Sutton County.
Elevation ground surface 2280 ft. (ARS Survey)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	145	145
Blind (off and on)	40	185
Yellow lime	80	265
Little water	5	270
Yellow lime	45	315
Water	20	335
Gray lime	135	470
Not reported	35	505
Lime and shale	40	545
Green shale	45	590
Gray lime	60	650 T.D.

Partial Sample Log (by H.R.Blank)

Description	Samples from Depth (Ft.)
All samples mixed together	0-200
Limestone, white, and dolomite, gray, both very fine-grained, with a little chert -- dolomite is minutely crystalline, but not porous.	200-230
Limestone, very dark blue-gray -- very fine-grained -- not porous	230-240
Limestone, light gray, rich in micro-fossils (miliolids?) -- not porous	240-260
Limestone, white, miliolid, and dolomite, light gray, minutely porous -- also small calcite crystals, a little gray chert. Driller reports a little water at 265	260-290
Dolomite, light gray, minutely crystalline, porous -- grinds up to "sand" -- also a little gray chert and colorless calcite	290-330
Dolomite, dark gray, minutely crystalline -- less porous than last sample -- also a little white limestone	330-340
Dolomite, dark gray to brownish-gray -- silty, minutely crystalline and in places porous -- alternating with limestone, white, fine-grained -- also a very little gray chert	340-390
Limestone, white, miliolid, fine-grained, dense	390-400
NOT ALL SAMPLES EXAMINED FROM THIS POINT ON	
First appearance of green clay, mixed with gray limestone	460-470
Siltstone, dark gray, calcareous, containing tiny crystals of FeS_2 -- also white limestone and green clay	540-550
Practically all green clay	550-580
Green clay, with some limestone and a little fine sand	580-590
Limestone, white and gray, with much dark clay, silt, and tiny cubes of pyrite	630-640

WELL LOG - Study No. 67

Vestal Askew - Water Well
Driller: Wesley C. Young Drilling Co.
Drilled: July 1960
Location: Lat. 30°36'11"N Long. 100°31'06"W
Near E line and about 0.6 mile from S line of Section 98, Block 9, TW&NGRR Survey, Sutton County.
Approximate ground surface elevation 2338 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	60	60
Blind	10.	70
Yellow lime	150	220
Blind	5	225
Yellow lime	10	265
Gray lime	50	315
Yellow lime	8	323
Water sand	25	348
Sand	3	351
Gray lime	9	360 T.D.

WELL LOG - Study No. 69

Surface Hole for El Paso Natural Gas Co. - #1-F Davis
Driller: Wesley C. Young Drilling Co.
Drilled: February 1959
Location: Lat. 30°36'44"N Long. 100°37'45"W
1320 ft. from N line and 1320 ft. from W line of Section 81, Block B, HE&WTRR Survey, Sutton County. N of Sonora on the Eldorado highway.
Approximate ground surface elevation 2309 ft. (EPNG Co.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	20	20
Blind	5	25
Yellow lime	140	165
Blind	5	170
Yellow lime	35	205
Flint	15	220
Lime	38	258
Gray lime	37	295
Yellow lime	40	335
Water sand	7	342
Water formation	18	360
Brown sandy lime	25	385
Gray lime	110	495
Gray shale - lime	20	515
Green shale	68	583
Shale and lime	22	605

WELL LOG - Study No. 73

C. L. Norsworthy - #1 Barton Heirs - Oil Test
Drilled: January-June 1950
Location: Lat. 30°36'10"N Long. 100°41'45"W
660 ft. from S line, 1980 ft. from W line, Section 105, Block B, HE&WTRR Survey, Sutton County. About 2-1/2 miles NW from Sonora.
Elevation: Drilling floor 2280 ft., Ground 2270 ft.
Datum not stated, but seems to be ground.
Notes by H.R.B. from Sample Log courtesy of Penn, Hills, and Turner, Midland, Texas.

Sample Log (from 0')

Description	Depth (Ft.)
Limestone and dolomite	0-460
Cherty limestone	140-170
Porous dolomite	270-300
Cherty limestone	320-330
Cherty limestone	360-370
No samples. "Top of Trinity group in sample gap"	460-470
Sandstone, limestone, red shale, green shale	470-730
Sandstone	730-780
"Base of Cretaceous and top of Permian by samples"	780
Green shale	780-880
No samples	880-980
Gray shale	980
*******	*******
	7944 T.D.

WELL LOG - Study No. 76

Paul Teas - No. 1 Mower - Oil Test
Drilled: March 1935
Location: Lat. 30°35'57"N Long. 100°16'39"W
1980 ft. from S line and 1980 ft. from W line, Section 39, Block 5, TW&NGRR Survey, Sutton County. About 10 miles W of E county line.
Elevation: 2349 ft. Datum not stated.
Notes by H.R.B. from Sample Log courtesy of Penn, Hills, and Turner, Midland, Texas.

Sample Log from 0'

Description	Depth (Ft.)
Limestone and dolomite	0-620
Porous dolomite	40-85
Porous dolomite	160-170
Very porous limestone	170-175
Porous dolomite	270-280
Slightly porous dolomite	345-360
Slightly porous dolomite	380-390
Wolfcamp fusilinids	300-750
*******	*******
	4930 T.D.

(This is a well where Cretaceous limestone apparently lies directly on Permian limestone.)

WELL LOG - Study No. 77

Water Well for Hunt - #1 R. L. Hardgrave - Gas Test
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: 1953-54
Location: Lat. 30°35'24"N Long. 100°22'48"W
NW corner Section 8, J. A. Robbins Survey, Sutton County. About 16 miles E from Sonora.
Elevation: Ground surface 2266 ft. (Estimated from drilling floor 2276 ft. on Midland Map Company land map.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and loose rock	2	2
Caliche	6	8
Yellow lime	32	40
White lime	20	60
Yellow lime	15	75
Brown sandy lime	30	105
Brown sand rock	12	117
Brown lime	13	130
White lime	20	150
Gray lime	40	190
White sandy lime	10	200
Water formation	51	251
Flint rock	4	255
Water	21	276
Gray lime	9	285 T.D.

WELL LOG - Study No. 80

Water Well for Pan American Petroleum Corp. - #2 Miers
Driller: Wesley C. Young Drilling Co.
Location: Lat. 30°35'43"N Long. 100°37'30"W
Approximate center of Section 82, Block B, HE&WTRR Survey, Sutton County. About 3 miles NE of Sonora.
Approximate ground surface elevation 2208 ft. (ARS Survey)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	30	30
Lime	35	65
Blind	15	80
Lime	35	115
Blind	15	130
Flint	35	165
Gray lime	35	200
Lime and flint	10	210
Blind	5	215
Water sand and gravel	25	240
Lime	10	250
Water formation sand	25	275
Lime	32	307 T.D.

WELL LOG - Study No. 86

Placid Oil Co. - #1 E. F. Mayer - Oil Test
Drilled: November 1950 - March 1951
Location: Lat. 30°35'08"N Long. 100°48'44"W
660 ft. from S line and 660 ft. from W line, Section 36, Block D, GC&SFRR Survey, Sutton County. About 8 miles W from Sonora.
Elevation: Drilling floor 2190 ft. Datum not stated, presumably drilling floor.
Notes by H.R.B. from Sample Log courtesy of Penn, Hills, and Turner, Midland, Texas.

Sample Log 70-400'; no log 400-1020'; log from 1020' on

Description	Depth (Ft.)
Limestone and dolomite (Cretaceous)	70-400
Very porous limestone	70-100
Very porous limestone	200-220
Very porous dolomite	220-230
A little sand or sandstone with limestone	380-390
"Top of Permian in sample gap between 400' and 1020'"	
*******	*******
	9239 T.D.

WELL LOG - Study No. 88

Water Well for El Paso Natural Gas Co.
#1 Clara Allison (J. E. Jones Drilling Co.)
Driller: Wesley C. Young Drilling Co.
Location: Lat. 30°34'27"N Long. 100°32'24"W
Located 660 ft. from S line and 660 ft. from E line, Section 9, EL&RR Survey, Sutton County.
Drilling floor elevation 2307 ft. (Muldrow Map Co.)
Approximate ground surface elevation 2297 ft. (Estimated)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
White lime (cave at 30, 62, 81, 103, 168, 198)	203	203
Yellow lime	37	240
Gray lime	30	270
White lime	11	281
Very little water	3	284
White lime	6	290
Water sand	15	305
White lime	26	331
Water	20	351 T.D.

WELL LOG - Study No. 89

City of Sonora - Water Well No. 4
Driller: Wesley C. Young Drilling Co.
Drilled: June 1953
Location: Lat. 30°34'12"N Long. 100°38'25"W
Located in valley of Lowrey Draw about 1/4 mile E of Sutton County court house.
Approximate ground surface elevation 2132 ft. (Estimated)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Clay and gravel	112	112
Hard lime	5	117
Clay and gravel	41	158
Hard honeycomb lime	17	175
Hard honeycomb sandy lime -- water	10	185
Sand	12	197
Hard lime	9	206 T.D.

(Water rose from 175 ft. to 165 ft.
Water level 167 ft. July 13, 1956.
Drawdown to 186 ft. yields 825 gallons per minute.)

WELL LOG - Study No. 90

City of Sonora - Water Well No. 2
Driller: Layne-Texas Co.
Drilled: 1938
Location: Lat. 30°34'18"N Long. 100°38'31"W
Located on top of ridge between Lowrey Draw and E. Fork Devils River (Dry Devils River) about 1/4 mile N of Sutton County court house.
Approximate ground surface elevation 2257 ft. (Estimated)

Driller's Log * (1)

Description	Thickness (Ft.)	Depth (Ft.)
White limestone	10	10
Caliche and boulders	2.5	12.5
Hard limestone	1.5	14
Limestone and caliche	5	19
Conglomerate	10	29
Caliche	3	32
Soft limestone	9	41
Hard limestone	5	46
Limestone and caliche	8	54
Very hard rock	4	58
Soft gray limestone	1.5	59.5
Hard limestone	26.5	86
Hard limestone and caliche	2	88
Hard limestone	13	101
Caliche and boulders	1	102
Hard limestone	14	116
Soft limestone	5	121
Hard layers in soft limestone	10	131
Flint	1.5	132.5
Flint layers and caliche	10.5	143
Hard layers and soft limestone	6	149
Very hard limestone	2	151
Hard layers and soft limestone	19	170
Hard limestone	1.5	171.5
Hard layers and soft limestone	22.5	194
Very hard limestone	6	200
Hard limestone	12	212
Limestone	6	218
Light gray limestone	10	228
Soft gray limestone	8	236
Hard gray limestone	17	253
Soft gray limestone	1	254
Red clay and boulders	20.5	274.5
Hard rock	1	275.5
Soft rock	4.5	280
Gravel and boulders; water	2	282
Light gray limestone	3	285
Soft limestone	3	288
Porous limestone; water	2.5	290.5
Very hard rock	2.5	293
Soft white limestone	3.5	296.5
Cavity; water	1.5	298
No sample	2	300
Tight sand	2	302
Brown flint	1	303 T.D.

(Static level 276 ft. below ground surface in 1938. Yield 420 gallons per minute in 1938.)

* Information from Broadhurst, Sundstrom, and Weaver (1), p. 248) and from Mr. R. M. McCarver, Sonora city manager.

WELL LOG - Study No. 91

Water Well for El Paso Natural Gas Co. - No. 1 Berger
Driller: Wesley C. Young Drilling Co.
Drilled: November 1958
Location: Lat. 30°34'53"N Long. 100°38'53"W
Located near Sonora municipal airport, in valley of E. Fork Devils River (Dry Devils River) just W of Sonora. SW 1/4 of Section 86, Block B, HE&WTRR Survey, Sutton County.
Approximate ground surface elevation 2132 ft. (Estimated)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Clay and gravel	74	74
Clay and gravel	81	155
Lime	15	170
Water	10	180
Yellow lime	15	195
Gray lime	30	225 T.D.

(Water rose 10 ft., from 170 to 160 ft.)

WELL LOG - Study No. 92

General Telephone Co. - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: July 1957
Location: Lat. 30°34'03"N Long. 100°38'36"W
At corner of telephone office building at Plum and Water Streets, Sonora, Sutton County, Texas.
Approximate ground surface elevation 2131 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Top Soil	10	10
Clay and gravel	25	35
Gray lime	55	90
Clay and gravel	35	125
Gray lime	27	152
Gravel & boulders, bearing water	15	167 T.D.

WELL LOG - Study No. 94

Hudspeth Hospital Ranch - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: April 1962
Location: Lat. 30°34'20" N Long. 100°55'57" W
Near center of Section 1017, Day Land & Cattle Co. Survey, Sutton County. About 9-1/2 miles S of N county line and 1-3/4 miles E of W county line.
Approximate ground surface elevation 2343 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	2	2
Brown lime	58	60
Yellow lime	60	120
White lime	110	230
Brown lime	30	260
Gray lime	70	330
White lime	74	404
Water formation	9	413
Brown lime	13	426
Brown lime and water	9	435
Gray lime	11	446 T.D.

WELL LOG - Study No. 96

Water Well for Hunt #1-28 J. W. Hardgrave - Gas Test
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: April 1954
Location: Lat. 30°33'45"N Long. 100°19'26"W
NW corner Section 28 (J. R. Robbins), Block 6, TW&NGRR Survey, Sutton County. About 19 miles E from Sonora.
Ground surface elevation 2246 ft. (Estimated from drilling floor 2256 ft. on Midland Map Company land map.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	1	1
Top rock	5	6
Blind (no returns)	6	12
Yellow lime	19	31
Brown lime	19	50
White lime	20	70
Yellow lime	30	100
White lime	10	110
Gray lime	30	140
White lime	10	150
Yellow lime	11	161
Sand	29	190
Water lime -- water	40	230
Gray lime	11	241 T.D.

WELL LOG - Study No. 97

Surface Hole for Shell Oil Co. - No. 1 Thelma Johnson
Driller: Wesley C. Young Drilling Co.
Location: Lat. 30°33'21"N Long. 100°37'10"W
Located 660 ft. from N line and 990 ft. from E line of Section 55, Block B, HE&WTRR Survey, Sutton County.
Approximate ground surface elevation 2266 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Light colored limestone	260	260
Dark gray limestone	38	298
Water	25	323
Sandy limestone	17	340
Hard limestone	160	500
Shale (dark gray silty, shaly limestone?)	-	500

(Log inferred by H.R.B. from conversation with driller)

WELL LOG - Study No. 98

Ward Broadcasting Co. (Sonora Radio Station) Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1961
Location: Lat. 30°33'03"N Long. 100°39'24"W
About 1.4 miles (7392 ft.) along U.S. Highway 277 SW from its intersection with U.S. Highway 290 in Sonora. Center of Section 93, Block B, HE&WTRR Survey, Sutton County.
Approximate ground surface elevation 2116 ft. (Aneroid)
Radio Station record shows elevation 2120 ft.

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	5	5
Clay and gravel	165	170
Lime	4	174
Water formation	26	200 T.D.

(Well cased with 5-1/2" pipe to 200 ft.)

WELL LOG - Study No. 100

John Ward - Water Well
Driller: Wesley C. Young Drilling Co.
Drilled: February 1960
Location: Lat. 30°33'59"N Long. 100°41'21"W
E 1/2 of Section 108, Block B, HE&WTRR Survey, Sutton County. About 3 miles W of Sonora.
Approximate ground surface elevation 2189 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	75	75
Blind	55	130
Yellow lime	20	150
Gray lime	55	205
Yellow lime	25	230
Water sand	20	250
Lime	20	270 T.D.

WELL LOG - Study No. 101

Hudspeth Hospital Ranch - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: April 1962
Location: Lat. 30°33'04"N Long. 100°54'40"W
SE corner Section 1, J. M. Armstrong Survey, Sutton County. About 11 miles S of N county line and 3 miles E of W county line. In draw near south edge of property.
Approximate ground surface elevation 2193 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	6	6
Brown lime	124	130
Gray lime	64	194
White lime and crevices	16	210
Pink lime	4	214
Water and porous lime	11	225
Hard gray lime	15	240
Brown porous lime and water	20	260 T.D.

WELL LOG - Study No. 102

Alfred Schwiening, Sr. (Mrs. Margaret Schwiening)
- Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1961
Location: Lat. 30°32'43"N Long. 100°07'07"W
NW 1/4 Section 45, Block A, GWT&PRR Survey, Sutton County.
Approximate ground surface elevation 2190 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	5	5
Gray lime	55	60
Yellow lime and crevices	43	103
Water formation and porous lime	9	112
Light gray lime	55	167
Dark gray lime	4	171 T.D.

WELL LOG - Study No. 103

Alfred Schwiening, Sr. (Mrs. Margaret Schwiening)
- Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1961
Location: Lat. 30°32'48"N Long. 100°09'07"W
N 1/2 Section 47, Block A, GWT&PRR Survey, Sutton County.
Approximate ground surface elevation 2261 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	3	3
Gray lime	47	50
Open cave	10	60
Yellow clay and boulders	18	78
Water sand	7	85
Light gray lime	20	105
Blue clay	15	110 T.D.

WELL LOG - Study No. 105

C. L. Norsworthy - No. 1 Sam Allison - Oil Test
Drilled: October 1952 - January 1953
Location: Lat. 30°32'29"N Long. 100°29'17"W
660 ft. from N line and 1980 ft. from E line, Section 44, Block B, HE&WTRR Survey, Sutton County. Just south of U.S. Highway 290, about 9 miles E by S from Sonora.
Elevation: Drilling floor 2353 ft. Datum not stated, supposedly drilling floor.
Notes by H.R.B. from Sample Log courtesy of Penn, Hills, and Turner, Midland, Texas.

Sample Log from 0'

Description	Depth (Ft.)
Limestone, with some dolomite and chert	500
Limestone, with some sandy streaks	30- 50
Porous limestone	60- 70
Very cherty limestone	210-260
Porous limestone and dolomite	320-350
Cherty limestone	350-370
Porous dolomite	400-410
"Top of Trinity"	500
No sample	500-510
Limestone, green shale, red shale, and sandstone	520-690
Sandstone (conglomeratic)	690-780
"Top of Permian"	780
Red Shale	780-800
Gray shale, with limestone	800
*******	*******
	7214 T.D.

WELL LOG - Study No. 106

Lea Allison - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: Spring 1960
Location: Lat. 30°31'16"N Long. 100°20'34"W
Apparently in N leg of Section 8, J. A. Manchaca Survey, Sutton County. About 18 miles ESE from Sonora. About 1-1/2 miles SSE from H. P. Allison house. With windmill.
Approximate ground surface elevation 2288 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Boulders	2	2
Gray lime	98	100
White lime	75	175
Yellow lime	75	250
Blue lime	10	260
Broken lime; crevices	16	276
Water formation	37	313
Brown lime	7	320 T.D.

WELL LOG - Study No. 108

Mrs. Dorothy Baker (G. B. Baker) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: May 1960
Location: Lat. 30°30'20"N Long. 100°15'39"W
Apparently in NW corner Section 11, Block 6, TW&NGRR Survey, Sutton County. About 23 miles ESE from Sonora. About 3/4 mile ESE from Baker house. With windmill.
Approximate ground surface elevation 2241 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Gray lime	20	20
Yellow lime	100	120
Blue lime	40	160
Brown lime	15	175
Water formation	9	184
White lime	11	195
Water formation	13	208
Gray lime	7	215 T.D.

(Yield 25 gallons per minute)

WELL LOG - Study No. 110

Water Well for Caroline Hunt Trust Estate's
Sterling Baker #1 - Gas Test
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: 1953
Location: Lat. 30°29'50"N Long. 100°17'04"W
SE corner Section 3 (S. C. Alexander), Block DC, Sutton County. About 24 miles ESE from Sonora.
Elevation: Ground surface 2164 ft. (Estimated from drilling floor 2174 ft. on Midland Map Company land map.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	1	1
Lime	5	6
Boulders	1	7
White lime	19	26
Blind (no returns)	30	56
Yellow lime	34	90
Gray lime	15	105
Blue lime	7	112
Sandy lime	6	118
Water	14	132
Lime	9	141
Gravel	9	150
Lime	10	160
Water sand and gravel	25	185
Water sand and gravel	10	195
Gray lime	15	210 T.D.

WELL LOG - Study No. 111

Albert Schultz Ranch - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Location: Lat. 30°29'05"N Long. 100°17'32"W
Located near center of N edge of Section 5 of E. B. Titus Survey, Sutton County.
Approximate ground surface elevation 2137 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Surface soil	3	3
Lime boulders	14	17
Sand rock	3	20
Sand and gravel	31	51
Sandy clay and gravel	13	64
Broken yellow lime	17	81
Sandy clay and gravel	10	91
Sand lime	19	110
Water sand and gravel	25	135 T.D.

WELL LOG - Study No. 114

C. L. Norsworthy, Jr. - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: April 1959
Location: Lat. 30°28'36"N Long. 100°12'29"W
Probably in E end of NE leg of M. C. Taylor Survey, (an irregular tract) west of Ft. Terret, Kimble County.
Approximate ground surface elevation 2268 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	50	50
Broken lime	16	66
Gray lime	54	120
Water sand	5	125
Gray lime	55	180
Dark gray lime	60	240
Green shale	10	250 T.D.

WELL LOG - Study No. 115

Joseph M. Vanderstucker (Mrs. Bessie Vanderstucker)
- Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: January 1961
Location: Lat. 30°28'25"N Long. 100°32'23"W
About 1900 ft. from E line and 1000 ft. from S line, Section 23, Block C, HE&WTRR Survey, Sutton County. N of road to Bryan Hunt Ranch.
Approximate ground surface elevation 2283 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	2	2
Limestone	15	17
Crevices	17	34
Limestone	299	333
Water formation	22	355 T.D.

(30 g.p.m.)

WELL LOG - Study No. 116

Joe Brown Ross - Water Well
Driller: Wesley C. Young Drilling Co.
Drilled: January 1960
Location: Lat. 30°27'27"N Long. 100°21'20W
In SE 1/4 of Section 14, Block 14, TW&NGRR Survey, Sutton County. About 17 miles E of Sonora on Highway U. S. 290 and 3 miles S.
Approximate ground surface elevation 2282 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Lime	33	33
Blind	3	36
Yellow lime	174	210
Blind	15	225
Yellow lime	45	270
Gray lime	85	365 T.D.

WELL LOG - Study No. 117

Joseph Vanderstucker (Mrs. Espy, lessee) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: February 1962
Location: Lat. 30°27'09"N Long. 100°36'19"W
About 1/8 mile from E line and 1/4 mile from N line, Section 69, Block C, HE&WTRR Survey, Sutton County.
Approximate ground surface elevation 2279 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	2	2
Gray lime	48	50
Broken lime and crevices	40	90
Gray lime	110	200
Yellow lime	60	260
White lime	98	358
Lime and water	7	365
Brown lime	10	375
Water formation	10	385
Brown lime	10	395 T.D.

(Well 6-1/2" diam. Estimated production 30 g.p.m.)

WELL LOG - Study No. 118

Collier Shurley Ranch - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1953
Location: Lat. 30°27'49"N Long. 100°37'15"W
About 1/2 mile from S line and 1/4 mile from E line, Section 75, Block C, HE&WTRR Survey, Sutton County.
Approximate ground surface elevation 2158 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	1	1
White lime	119	120
Blind	70	190
Blue lime	30	220
Blue shale	25	245
Water lime	33	278
Blue shale	10	288 T.D.

WELL LOG - Study No. 119

Wesley Sawyer Ranch - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Location: Lat. 30°27'54"N Long. 100°46'57"W
Located on W edge, Section 190, Block C, HE&WTRR Survey, SW of Sonora, Sutton County.
Approximate ground surface elevation 2072 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	6	6
Gray lime	164	170
Lime and crevices	40	210
Water formation	30	240
Gray lime	5	245 T.D.

(Well 6-1/2" diam.)

WELL LOG - Study No. 120

Water Well for Union Oil Co. of California
No. 1 Aldwell Brothers
Driller: Wesley C. Young Drilling Co.
Drilled: April 1959
Location: Lat. 30°27'03"N Long. 100°48'57"W
NE 1/4 Section 22, Block CC, Sutton County.
About 20 miles SW of Sonora.
Drilling floor elevation 2109 ft. (Midland Map Co.)
Approximate ground surface elevation 2099 ft. (Estimated)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Gravel	25	25
Lime	5	30
Blind	5	35
Lime	25	60
Blind	8	68
Lime	32	100
Blind	6	106
Lime	55	161
Gray lime	12	173
Yellow lime	12	185
Lime	8	193
Blind	9	202
Lime	33	235
Water sand	45	280
Gray lime	10	290 T.D.

WELL LOG - Study No. 121

William Nichols - #1 J. B. Ross (Stanolind F-7) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: April 1954
Location: Lat. 30°26'54"N Long. 100°23'26"W
Located in Section 26, Block 14, TW&NGRR Survey, Sutton County.
Approximate ground surface elevation 2215 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Surface rock	4	4
Caliche	36	40
Blind	10	50
Yellow lime	65	115
Brown lime	11	126
Flint caves	25	151
Gray lime	14	165
Yellow lime	35	200
Gray lime	50	250
Water lime - water	40	290
Water sand	30	320
Gray lime	15	335 T.D.

WELL LOG - Study No. 123

Jerry N. Shurley (Mrs. Velma Shurley) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: May 1959
Location: Lat. 30°26'07"N Long. 100°44'50"W
About 1/2 mile from N line and 1140 ft. from W line, Section 164, Block C, HE&WTRR Survey, Sutton County. About 1 mile SW of the house.
Approximate ground surface elevation 2107 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	2	2
Caliche	18	20
Yellow limestone	60	80
Gray limestone	80	160
White limestone	40	200
Broken yellow limestone	39	239
Water formation	21	260
Dark gray limestone	10	270 T.D.

(Water test at 20 g.p.m. Possible production - 50 g.p.m.)

WELL LOG - Study No. 125

Gerald Nicks - Water Well
Driller: Wesley C. Young Drilling Co.
Drilled: October 1959
Location: Lat. 30°25'26"N Long. 100°53'04"W
Located in Section 2 of Mrs. N. S. Goldman Survey on Old Hudspeth Ranch in SW Sutton County.
Approximate ground surface elevation 2110 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	70	70
Gray lime	60	130
Blind	30	160
Lime	43	203
Gray lime	67	270
Water sand	5	275
Gray lime	70	345 T.D.
Green shale	below 345 ft.	

WELL LOG - Study No. 128

Surface Hole for Pan American Petroleum Co. No. 1 Thelma Espy
Driller: Wesley C. Young Drilling Co.
Drilled: November 1957
Location: Lat. 30°23'48"N Long. 100°33'06"W
NE 1/4 Section 32, Block C, HE&WTRR Survey, Sutton County. S of Sonora 18 miles out Ranch Road 1691, 3 miles S of end of pavement.
Drilling floor elevation 2169 ft. (Midland Map Co.)
Approximate ground surface elevation 2159 ft. (Estimated)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	98	98
Blind	7	105
Yellow lime	80	185
Gray lime	45	230
Water sand	30	260
Water, sand and gray lime	40	300
Gray lime	90	390
Gray lime and shale	25	415
Green shale	85	500

WELL LOG - Study No. 129

Stanton Bundy (Alamo Freight Lines, fee) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: October 1960
Location: Lat. 30°22'38"N Long. 100°13'09"W
About 2600 ft. from N line and 1400 ft. from E line of Section 6, Block 7, TW&NGRR Survey, Sutton County. About 6 miles from east county line and 6-1/2 miles from south county line.
Approximate ground surface elevation 2192 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	18	18
Gray lime	12	30
Yellow lime	70	100
Gray lime	100	200
Water, 1/2 gallon per minute	5	205
Yellow lime	30	235
Water, 5 gallons per minute	5	240
White lime	5	245
Water formation	10	255
Dark gray lime	15	270 T.D.

(Estimated production 30 gallons per minute.)

WELL LOG - Study No. 130

Bill Wade (M. D. Selman) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: February 1962
Location: Lat. 30°22'53"N Long. 100°16'11"W
NE 1/4 Section 19, Block 7, TW&NGRR Survey, Sutton County, SE part of county, S end of Ross Road.
Approximate ground surface elevation 2263 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	2	2
Caliche	18	20
White lime	150	170
Yellow lime	40	310
Water formation	4	314
Gray lime	6	320
Water formation	5	325
Brown lime	10	335
Water formation	10	345
Brown lime	12	357 T.D.

(Well 6-1/2" diam. Estimated production 40 g.p.m.)

WELL LOG - Study No. 131

Alice Bundy & Son (Albert L. Wade) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: June 1961
Location: Lat. 30°21'02"N Long. 100°10'44"W
SE corner Shelby C. Turnage Survey, Section 70, Sutton County. About 3-1/2 miles from the east line and 4-1/2 miles from the south line of the county. Well with windmill in "diamond" pasture.
Approximate ground surface elevation 2318 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	2	2
Caliche	23	25
White lime	35	60
Brown lime	120	180
Gray lime	60	240
Yellow lime	60	300
White lime	25	325
Gray lime	12	337
Water formation	8	345
Gray lime	8	353
Water formation	9	362
Gray lime	5	367 T.D.

(Yield 50 gallons per minute.)

WELL LOG - Study No. 132

Stanton Bundy (Albert L. Wade, fee) - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: May 1961
Location: Lat. 30°21'08"N Long. 100°11'42"W
About 3800 ft. from W line and 1100 ft. from S line of Section 70, Shelby C. Turnage Survey, Sutton County. About 4-1/2 miles from E county line and 4-1/2 miles from S county line. Well with windmill in west pasture.
Approximate ground surface elevation 2312 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	1	1
Caliche	9	10
Gray lime	25	35
White lime	60	95
Gray lime	40	135
White lime	49	184
Gray lime	36	220
Yellow lime	30	250
Blue lime	22	272
Yellow lime	38	310
Water formation	15	325
White lime	18	343
Water formation	11	354 T.D.

(Production 10 gallons per minute.)

WELL LOG - Study No. 133

Mrs. M. B. Sawyer - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: August 1951
Location: Lat. 30°21'43"N Long. 100°12'47"W
About 2800 ft. from N line and 2000 ft. from E line, Section 3, Block V-23, G. Thompson Survey, Sutton County. Eagle Well Ranch, SE part of county.
Approximate ground surface elevation 2297 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil	1	1
Yellow white lime	29	30
Blind	5	35
Yellow lime	9	44
Blind	9	53
Yellow lime	7	60
Blind	10	70
Yellow lime	45	115
Blind	45	160
Yellow lime	117	277
Blind	14	291
Yellow lime	36	327
Blind	4	331
Yellow lime	20	351
Water lime	1	352
Gray lime	14	366
Water lime	7	373
Gray lime	13	386 T.D.

WELL LOG - Study No. 134

Water Well for Eisner - No. 1-c Mack Cauthorn
Driller: Wesley C. Young Drilling Co.
Drilled: December 1957
Location: Lat. 30°20'58"N Long. 100°38'09"W
Section 86, Block C, HE&WTRR Survey, Sutton County. Approx. 20 miles SW of Sonora on Del Rio Highway. About 4-1/2 miles from Sutton-Edwards county line.
Approximate ground surface elevation 2218 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
White lime	10	10
Yellow lime	165	175
Lime and flint	35	210
Lime	25	235
Brown lime	35	270
Gray lime	50	320
Blind	7	327
Lime	18	345
Water sand	15	360
Lime	10	370
Gray lime	10	380
Sandy lime	20	400
Gray lime	84	484 T.D.

WELL LOG - Study No. 135

Dan Cauthorn Ranch - Water Well, 6-3/8" diam.
Driller: Sonora Drilling Co. (J. A. Letsinger)
Location: Lat. 30°18'37"N Long. 100°43'20"W
About 800 ft. from W line and 1500 ft. from S line of Section 27, GS&SFRR Survey, Sutton County. About 250 ft. N of F.M. Road 189, 5.2 miles SW from its intersection with U.S. 277. Windmill on hillside.
Approximate ground surface elevation 2179 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Limestone	300	300
Water formation	30	330
Gray lime	15	345
Broken lime and water	15	360
Blue lime	10	370 T.D.

WELL LOG - Study No. 136

Surface Hole for Shell Oil Co. - No. 1 Holman
Driller: Wesley C. Young Drilling Co.
Drilled: November 1959
Location: Lat. 30°17'16"N Long. 100°36'00"W
Section 40, CCSD&RGNGRR Survey, Edwards County. SW of Sonora 23 miles on the Rock Springs highway.
Approximate ground surface elevation 2260 ft.
(Midland Map Co.)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Yellow lime	100	100
White lime	65	165
Blind	5	170
Yellow lime	10	180
Blind	7	187
Brown lime	31	218
Brown lime and flint	40	258
Brown lime	32	290
Gray lime	10	300
Yellow lime	55	355
Lime	5	360
Water-sand	10	370
Sandy lime	20	390
Gray lime	95	485
Gray lime and shale	25	510
Green shale	40	550
Gray lime	25	575
Green shale	35	610
Gray lime	10	620

WELL LOG - Study No. 137

John Cauthorn - Water Well No. 1
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: August-September 1962
Location: Lat. 30°17'04"N Long. 100°47'38"W
About 2500 ft. from N line and about 900 ft. from E line of Section 17 (W. Sueltemeyer), GC&SFRR Survey, Val Verde County. Just south of the Sutton-Val Verde county line.
Approximate ground surface elevation 2179 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	1	1
Gray lime	24	25
Brown lime	30	55
Dark brown lime	45	100
Light brown lime and chert	50	150
Brown lime and chert	50	200
Gray lime and chert	40	240
Gray shale	6	246
Brown lime	39	285
Dark gray lime	15	300
Gray lime (crevices)	60	360
Brown lime and water	15	375
Brown lime	9	384 T.D.

(Yield 25 gallons per minute)

Partial Sample Log (by H.R.Blank)

Description	Samples from Depth (Ft.)
Crevice -- returns	330-343
Limestone, white, lithographic, not porous	343-350
Dolomite and dolomitic limestone, dark gray -- minutely crystalline and minutely porous	350-358
Dolomite and dolomitic limestone, like 350-358, with some dark lithographic limestone and a little calcite -- no chert seen.	358-372
Dolomite and dolomitic limestone, dark gray and porous, also white and dense -- both types minutely crystalline	372-384 T.D.

WELL LOG - Study No. 138

Dan J. Harrison Ranch - Water Well
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: September 1960
Location: Lat. 30°15'47"N Long. 100°27'46"W
Near SW corner Section 209, CCSD&RGNGRR Survey, Edwards County. About 1-1/2 miles south of N line of county, and about 2 miles south of ranch headquarters.
Approximate ground surface elevation 2311 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	5	5
Yellow limestone	75	80
White limestone	100	180
Yellow limestone	80	260
Brown limestone	115	375
Water formation	10	385
Limestone	8	393
Water formation	7	400
Limestone	11	411 T.D.

WELL LOG - Study No. 139

Texas Agricultural Experiment Station, Substation #14 Headquarters - Water Well
Location: Lat. 30°15'53"N Long. 100°33'59"W
About 1400 ft. from W line and 400 ft. from S line, SW 1/4 Section 63, CCSD&RGNGRR Survey, Edwards County. Out Rocksprings highway about 25 miles from Sonora.
Approximate ground surface elevation 2248 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Caliche and shell	17	17
Yellow lime	8	25
White lime	18	43
Yellow lime	34	77
Gray lime	68	145
Yellow lime	53	198
White lime	80	278
Yellow lime	49	327
Blue lime	21	348
White lime	25	373
Cave	2	375
First water	-	375
Course lime with crystals and flint	10	385
Gray lime, hard	22	407
Gray lime, soft	15	422
Brown lime, hard	3	425 T.D.

(Static water level -- 373 ft. Gauge shows no drawdown. Pump set at depth 420 ft. Capacity -- 23 gpm in low tank -- 22 gpm in high tank.)

WELL LOG - Study No. 140

R. J. Caraway - #1 Guida Rose - Shut-in Gas Well
Drilled: August 1950 - May 1951
Location: Lat. 30°14'25"N Long. 100°49'33"W
2310 ft. from N line and 330 ft. from E line, Section 2, GC&SFRR Survey, Val Verde County. About 8 miles W of E county line and about 4 miles S of N county line.
Elevation: Drilling floor 1971 ft. Datum not stated, presumably drilling floor.
Notes by H.R.B. from Sample Log courtesy of Penn, Hills, and Turner, Midland, Texas

Sample Log (from 0')

Description	Depth (Ft.)
"Starts in Cretaceous (Washita)"	
Limestone and dolomite	0-340
Porous limestone and dolomite	150-180
"Top of Trinity group by samples"	340
Green shale, gray shale, limestone, and sandstone	340-570
Chiefly limestone	570-730
Sandstone and gray shale	730-760
"Top of Permian by samples"	760
Gray shale	760-800
*******	*******
	11,590 T.D.

WELL LOG - Study No. 141

John Cauthorn - Water Well #2
Driller: Sonora Drilling Co. (J. A. Letsinger)
Drilled: September - October 1962
Location: Lat. 30°13'57"N Long. 100°49'14"W
About 1300 ft. from W line and about 300 ft. from S line of Section 1 (N. G. King), GC&SFRR Survey, Val Verde County. About 3-1/2 miles S from Sutton-Val Verde county line and about 8 miles E from Devils River.
Approximate ground surface elevation 2037 ft. (Aneroid)

Driller's Log

Description	Thickness (Ft.)	Depth (Ft.)
Soil and boulders	1	1
Gray lime	19	20
Yellow lime	25	45
Gray lime	105	150
Brown lime	42	192
Gray lime	36	228
Brown lime	26	254
Gray lime and water	66	320
Dark gray lime and shale	101	421 T.D.

Yield 1/2 gallon per minute.

(Note: An incomplete series of samples, beginning at depth 250', was examined from this well. These suggest that the "brown lime" at depth 228', and possibly that at depth 150' also, may be dolomite. H.R.B.)

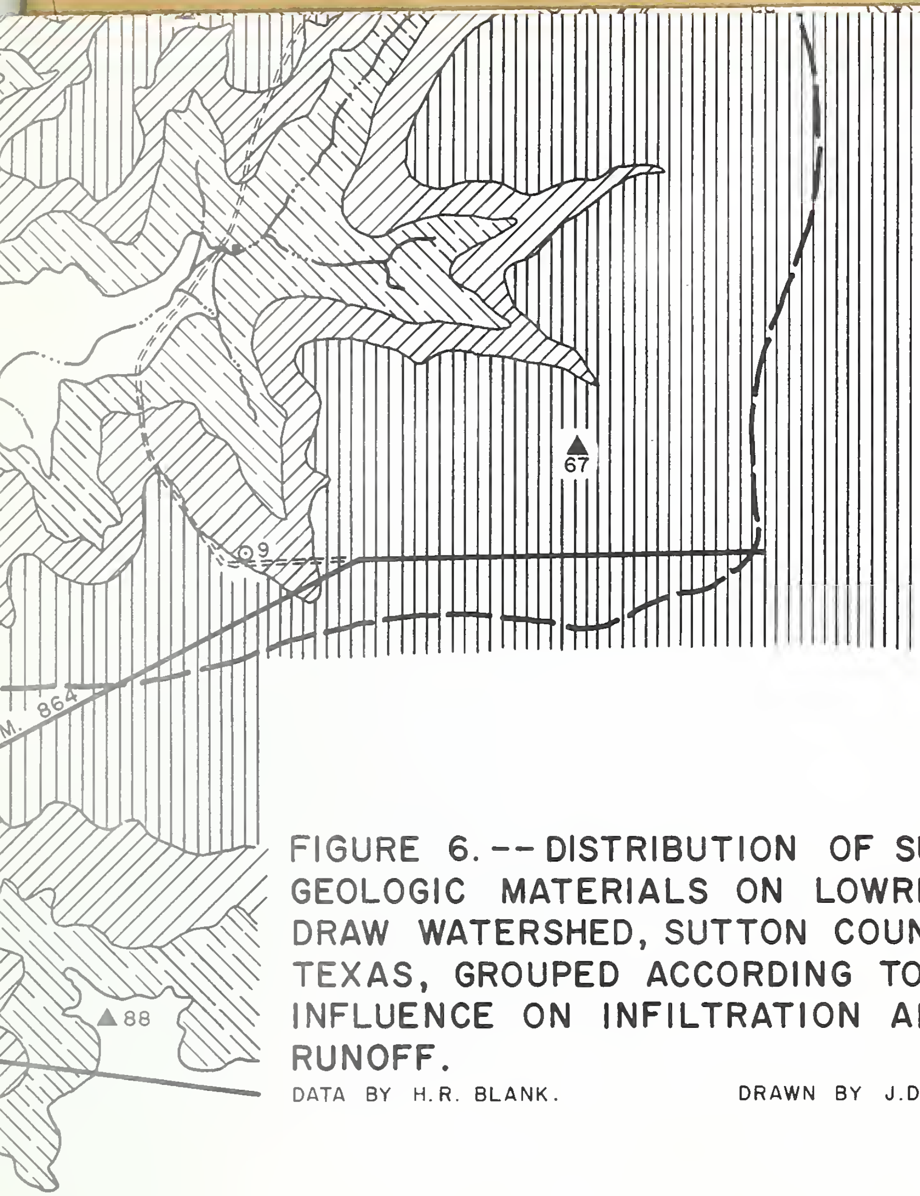

FIGURE 6.--DISTRIBUTION OF SURFACE GEOLOGIC MATERIALS ON LOWREY DRAW WATERSHED, SUTTON COUNTY, TEXAS, GROUPED ACCORDING TO THEIR INFLUENCE ON INFILTRATION AND RUNOFF.

DATA BY H.R. BLANK. DRAWN BY J.D. CHILCOAT.

SCALE IN MILES

1 ½ 0 1

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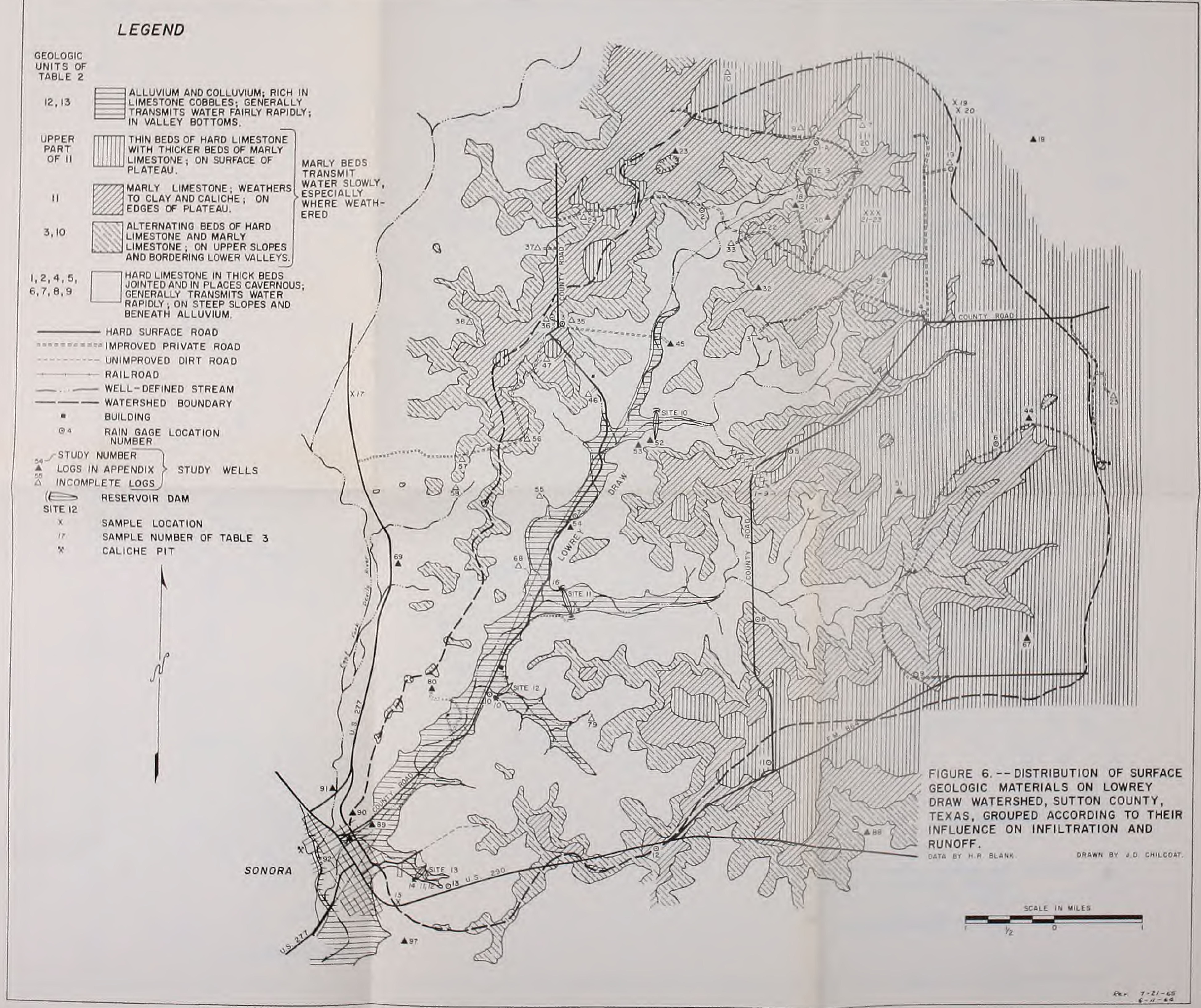
LEGEND
GEOLOGIC UNITS OF TABLE 2
12, 13
ALLUVIUM AND COLLUVIUM; RICH IN LIMESTONE COBBLES; GENERALLY TRANSMITS WATER FAIRLY RAPIDLY; IN VALLEY BOTTOMS.
UPPER PART OF 11
THIN BEDS OF HARD LIMESTONE WITH THICKER BEDS OF MARLY LIMESTONE; ON SURFACE OF PLATEAU.
11
MARLY LIMESTONE; WEATHERS TO CLAY AND CALICHE; ON EDGES OF PLATEAU.
3, 10
ALTERNATING BEDS OF HARD LIMESTONE AND MARLY LIMESTONE; ON UPPER SLOPES AND BORDERING LOWER VALLEYS.
MARLY BEDS TRANSMIT WATER SLOWLY, ESPECIALLY WHERE WEATHERED
1, 2, 4, 5, 6, 7, 8, 9
HARD LIMESTONE IN THICK BEDS JOINTED AND IN PLACES CAVERNOUS; GENERALLY TRANSMITS WATER RAPIDLY; ON STEEP SLOPES AND BENEATH ALLUVIUM.
HARD SURFACE ROAD
IMPROVED PRIVATE ROAD
UNIMPROVED DIRT ROAD
RAILROAD
WELL-DEFINED STREAM
WATERSHED BOUNDARY
BUILDING
⊙4 RAIN GAGE LOCATION NUMBER
54 STUDY NUMBER
▲ LOGS IN APPENDIX
55 △ INCOMPLETE LOGS
STUDY WELLS
RESERVOIR DAM
SITE 12
X SAMPLE LOCATION
17 SAMPLE NUMBER OF TABLE 3
CALICHE PIT
N
SONORA
U.S. 277
U.S. 290
COUNTY ROAD
LOWREY DRAW
F.M. 864
East Fork Devils River
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
SCALE IN MILES
½
0
1

FIGURE 6.--DISTRIBUTION OF SURFACE GEOLOGIC MATERIALS ON LOWREY DRAW WATERSHED, SUTTON COUNTY, TEXAS, GROUPED ACCORDING TO THEIR INFLUENCE ON INFILTRATION AND RUNOFF.

DATA BY H.R. BLANK. DRAWN BY J.D. CHILCOAT.

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Map to Accompany "Geology and Groundwater Studies in a Part of the Edwards Plateau of Texas, Including Sutton and Adjacent Counties," ARS 41-103

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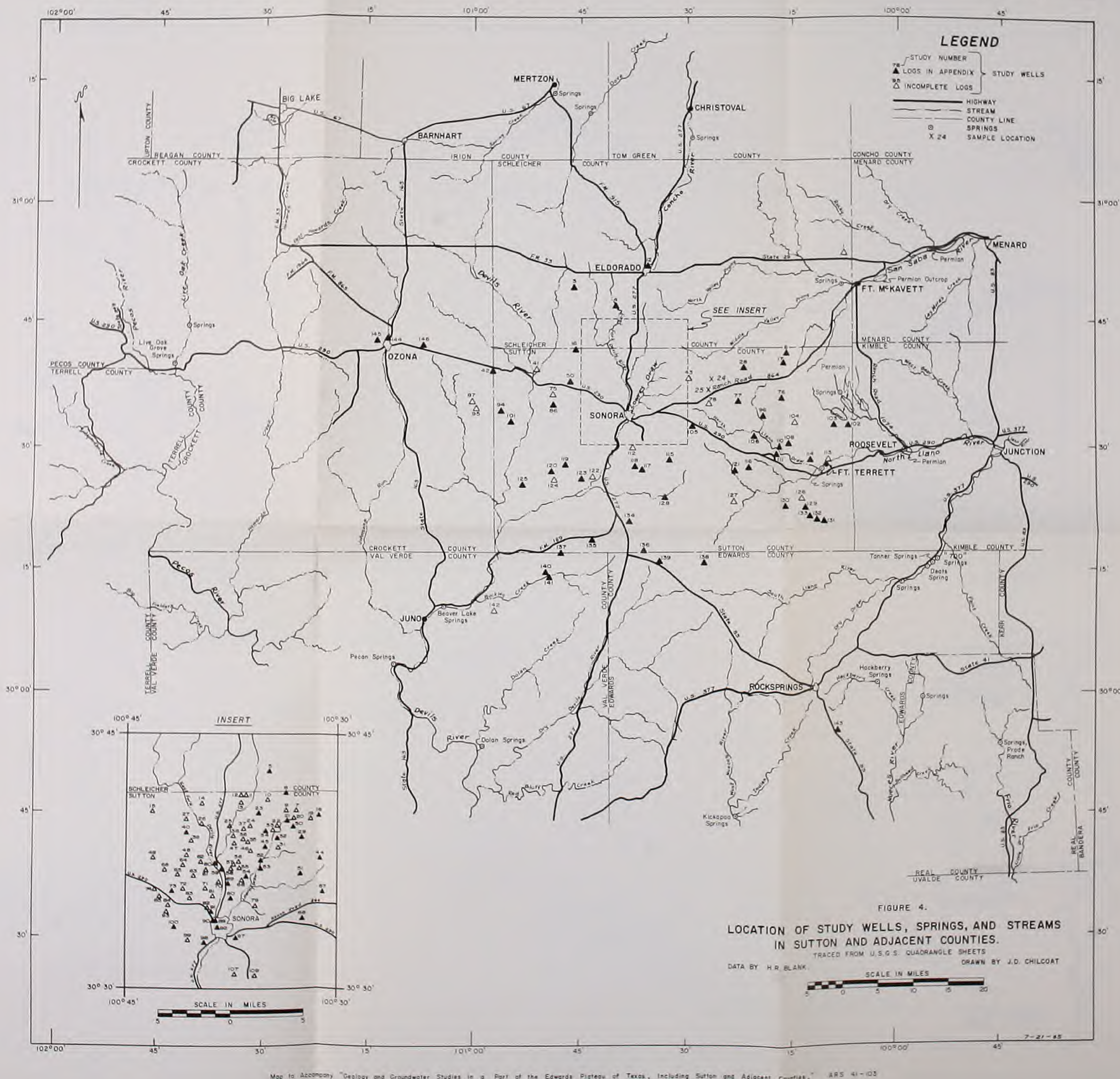

FIGURE 4.

LOCATION OF STUDY WELLS, SPRINGS, AND STREAMS IN SUTTON AND ADJACENT COUNTIES.

TRACED FROM U.S.G.S. QUADRANGLE SHEETS

DATA BY H.R. BLANK

DRAWN BY J.D. CHILCOAT

SCALE IN MILES

7-21-65

Map to Accompany "Geology and Groundwater Studies in a Part of the Edwards Plateau of Texas, Including Sutton and Adjacent Counties," ARS 41-103

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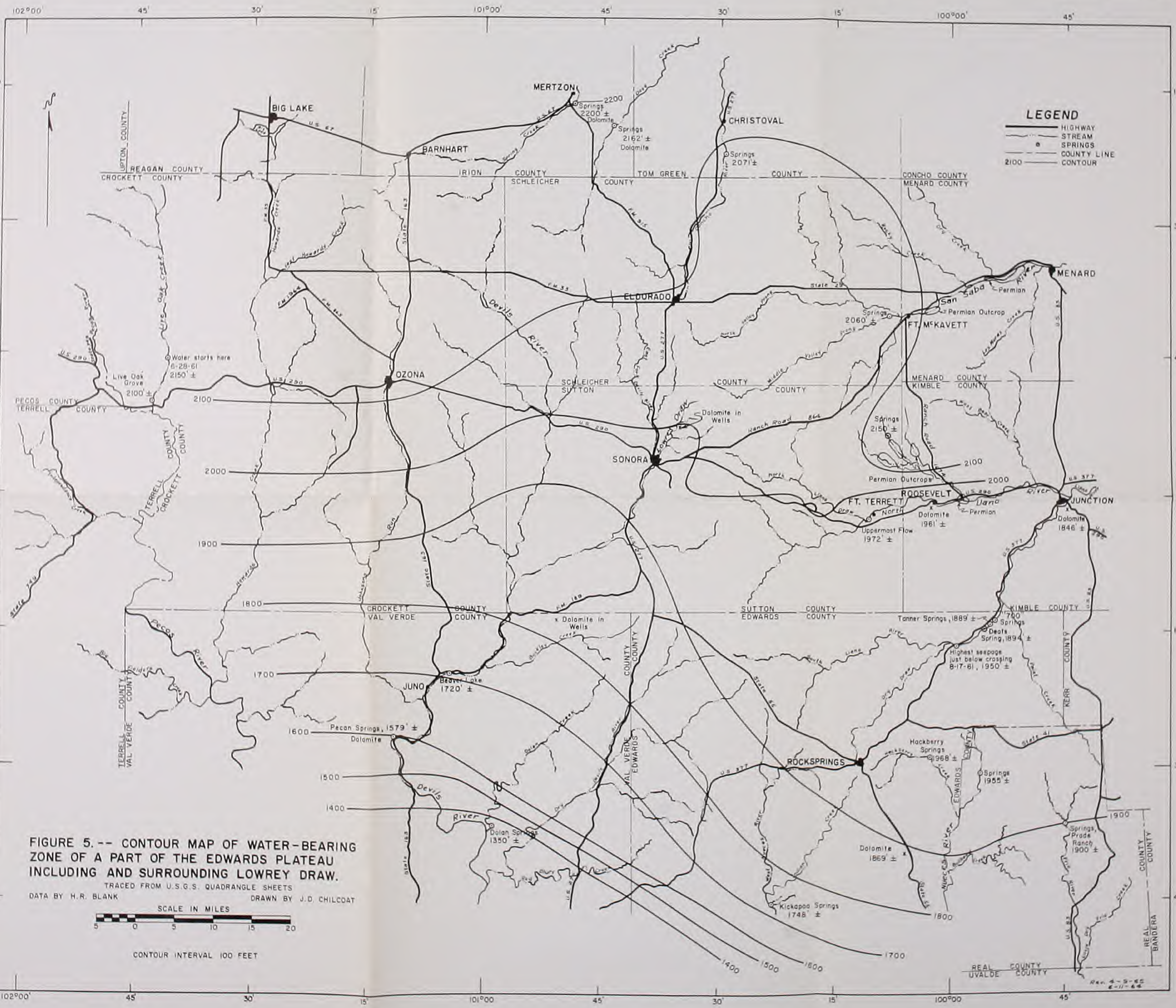

FIGURE 5.-- CONTOUR MAP OF WATER-BEARING ZONE OF A PART OF THE EDWARDS PLATEAU INCLUDING AND SURROUNDING LOWREY DRAW.

TRACED FROM U.S.G.S. QUADRANGLE SHEETS

DATA BY H.R. BLANK

DRAWN BY J.D. CHILCOAT

SCALE IN MILES

5 0 5 10 15 20

CONTOUR INTERVAL 100 FEET

Map to Accompany "Geology and Groundwater Studies in a Part of the Edwards Plateau of Texas, Including Sutton and Adjacent Counties," ARS 41-103

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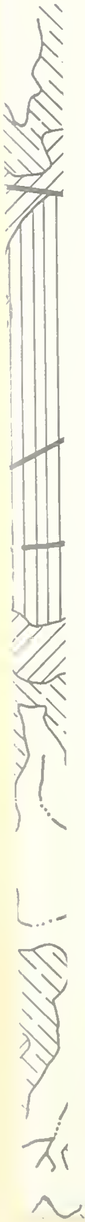

LEGEND

GEOLOGIC UNITS OF TABLE 2		
12, 13	▤	ALLUVIUM AND COLLUVIUM; RICH IN LIMESTONE COBBLES; GENERALLY TRANSMITS WATER FAIRLY RAPIDLY; IN VALLEY BOTTOMS.
UPPER PART OF 11	▥	THIN BEDS OF HARD LIMESTONE WITH THICKER BEDS OF MARLY LIMESTONE; ON SURFACE OF PLATEAU.
11	▨	MARLY LIMESTONE; WEATHERS TO CLAY AND CALICHE; ON EDGES OF PLATEAU.
3, 10	▧	ALTERNATING BEDS OF HARD LIMESTONE AND MARLY LIMESTONE; ON UPPER SLOPES AND BORDERING LOWER VALLEYS.
1, 2, 4, 5, 6, 7, 8, 9	☐	HARD LIMESTONE IN THICK BEDS JOINTED AND IN PLACES CAVERNOUS; GENERALLY TRANSMITS WATER RAPIDLY; ON STEEP SLOPES AND BENEATH ALLUVIUM.

MARLY BEDS TRANSMIT WATER SLOW ESPECIALLY WHERE WEAT ERED

———————	HARD SURFACE ROAD
===========	IMPROVED PRIVATE ROAD
- - - - - - - - - - -	UNIMPROVED DIRT ROAD
——+——+——+——	RAILROAD
——— . . . ———	WELL-DEFINED STREAM
——— — ——— — ———	WATERSHED BOUNDARY
■	BUILDING
⊙ 4	RAIN GAGE LOCATION NUMBER
54	STUDY NUMBER
▲	LOGS IN APPENDIX
55 △	INCOMPLETE LOGS

STUDY NUMBER, LOGS IN APPENDIX, INCOMPLETE LOGS: STUDY WELLS

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